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THE IMPACT OF COATING TYPE ON THE ABRASION RESISTANCE AND THE RESISTANCE TO COLD LIQUIDS OF LACQUERED SURFACES

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ABSTRACT

This paper investigates the impact of the type of coating of the stained lacquered surface of medium–density fiberboard (MDF) on the resistance to abrasion and the resistance to cold liquids. Veneer-faced MDF samples were stained and lacquered with two types of clear coatings: polyurethane (PU) and UV-curable polyacrylic (UV-PA) coating. The difference in the formulation of PU and UV-PA coating was detected by IR spectroscopy. Since PU coatings show tendency towards yellowing, the goal of this research was to examine the possibility of replacement of this type of coating by UV-PA coating regarding the resistance of UV-PA coating to abrasion and to cold liquids. It was found that the samples lacquered with PU coating had higher abrasion resistance (observing the changes during 600 cycles) and higher resistance to cold liquids, compared to samples lacquered with UV-PA coating. The higher abrasion resistance of surfaces lacquered with PU coating was related to formulation of this type coating and higher value of dry film thickness, which is due to application method. The lacquered samples were tested to resistance to liquids (water and cleansing agent) to which surfaces will most likely be exposed during use. In order to simulate the cleaning conditions that can be expected in practice, cleansing agent and water were applied to test surfaces by spraying, rubbed to the surface by microfiber cloth, and whipped with dry soft cloth. The results of this test confirmed the lower resistance of surfaces lacquered with UV-PA coating to the effect of cleansing liquids, compared to surfaces lacquered with PU coating. The wood surface-coating interface was observed by microscopy.

Key words: PU coating, UV-PA coating, MDF, abrasion resistance, resistance to cold liquids

1. INTRODUCTION

In addition to protection features, one of the main tasks in the wood surface finishing is decorative treatment of the surface. The goal of decorative treatment is to highlight the natural texture of precious wood species and „ennoble" or enhance the aesthetic quality of less attractive surfaces (e.g. surface of particleboards, MDF, HDF...). In addition, it is possible to "cover-up" and/or change the natural color of wood in an almost unlimited range of shades in regard with the aesthetic preferences of buyers. In this way, the wood surface finishing, offers wide possibilities in terms of customers' demands and trends that are currently ongoing in the market of furniture and wood products.

The white color gives a visual sense of clarity and openness. In the wood surface finishing this effect can be achieved by staining procedure which involves changing the color of wood while preserving it`s natural texture. In this way, we get the combined effect: purity, elegance and modernity of white colorblends with the warmth of wood as a natural material.

Stains present a dispersion of pigments or dyes in an appropriate solvent, meaning that staining procedure requires further application of transparent coating to protect the stained surface from the harmful effects of the environmental factors. In terms of different types of coatings, consumers often opt for polyurethane (PU) coatings because of their often-conflicting properties: good flexibility and high values of mechanical properties of lacquered surfaces (Jaić and Živanović-Trbojević, 2000). This type of coating is characterized by strength and hardness, abrasion resistance (Çakicier *et al*., 2011), flexibility, good adhesion and chemical resistance (Graystone and Franco, 2009). Thanks to these properties, PU coatings are often used in the function of primer and /or top coats. One disadvantage that occurs in PU coatings is their tendency towards yellowing under the action of ultraviolet radiation (Jaić and Živanović-Trbojevic, 2000; Streitberger and Goldschmidt, 2007). This effect is due to decomposition of aliphatic polyisocyanates used as a hardener in polyester resins (basic coating). Tendency towards yellowing of the coating is especially visually emphasized in areas that are stained in white, losing the effect of "clean surface". One way to eliminate this shortcoming is the use of aromatic isocyanate as a hardener and this solution is found in coatings that are intended for outdoor environment. On the other hand, a large number of manufacturers are opting for replacement of PU coating with other types of coatings, which show no tendency towards yellowing. Because of the great similarity in formulation of polyacrylic (PA) and PU coating, and thus the similarities in the properties of dry film of coating, consumers often choose to lacquerthe white stained surfaces with polyacrylic coatings. To ensure the viability of this solution it is necessary to preserve the high values of other properties of lacquered surface. Previous studies showed that polyisocyanate-crosslinked acrylic films provide excellent stability against chemicals and solvents, which makes them favorable for the topcoats (Müller and Poth, 2006; Lee and Kim, 2006). In addition, UV-based acrylic coatings show excellent properties in terms of resistance to abrasion, impact resistance and toughness (Lee and Kim, 2006). Depending on the position of the surface in the product, as well as the purpose of the product itself, it is necessary to determine the properties of lacquered surface that will define the durability of product in service. The aim of this study is to analyze the effect of substitution of PU coating with UV-PA coating on the surfaces of stained veneer-faced MDF boards, in relation to the abrasion resistance and the resistance to cold liquids. In order to test how maintenance procedure affect the properties of lacquered surfaces, special cleaning procedure, which is suitable for buildings with a large number of users and the constant use of the product, was conducted.

2. MATERIALS AND METHODS

2.1 Choice of the samples

In order to achieve cost savings, wood-based panels e.g. plywood, MDF, HDF... are often used instead of wood as base material for the production of final products. Given their rough texture enrichment of their surface includes application of solid materials (veneers, foils and laminates) and application of opaque coating that completely cover the surface appearance of the substrate. In this paper, samples of beech-veneered MDF were used, with the sampling been performed from corpus furniture from the market (cabinet boards). According to the manufacturer, the boards were prepared prior to coating by sanding in the standard system. After sanding, the samples were stained in white color with nitro stain. Then, the samples were lacquered with: PU coating (I group) and UV-PA coating (II group). PU coating (Zvezda Helios, Gornji Milanovac) was applied in one primer coat (2K PUR LAK OSNOVNI) with application rate of 250 g/m^2 and one top coat (2K PUR LAK ZAVRSNI) with application rate of 150 g/m^2, by hand spraying technique. Calculation of the application rate was performed based on total consumption of the coating to the total sum of lacquered surfaces. The second group of samples was coated with UV-curing polyacrylic coating (Helios, Slovenia). Application of UV-PA coating was performed on the roller machine in two coats: one coat of primer (417121 UVEHEL BASECOAT) and one top coat (417116 UVEHEL TOP COAT). The amount of application rates for primer and top coats were 25 g/m^2 and 10 g/m^2, respectively. The curing of the coatings was carried out by passing of samples under UV lamp having input power of 100 W/cm. Technical characteristics of PU and UV-PA coatings, received by manufacturers, are given in Table 1.

2.2 IR-spectroscopy

Since the samples were taken from the market and the information about the process of surface finishing was obtained from the manufacturer, the analysis of the IR spectrum of coatings was conducted to determine the credibility of the data. The same method was used for surfaces where the damages occurred due to the effects of cleansing agents to determine whether these changes are of chemical or mechanical nature.

Table 1. *Technical specification of PU and UV-PA coating*

Type of coating	PU coating		UV-PA coating	
Function of coating	Primer	Top coat	Primer	Top coat
Solid content (%)	40±2 (component A)	46±2 (component A)	100	100
Rate of components	2:1	2:1	/	/
Added diluents (%)	5-10	5-10	/	/
Working viscosity	16-18 s (DIN 4/20˚C)	16-18 s (DIN 4/20˚C)	90-120 (DIN 6/20˚C)	80-100 (DIN 4/20˚C)
Application rate (g/m^2)	120-150	120-200	12-18	3-8

2.2 IR-spectroscopy

Since the samples were taken from the market and the information about the process of surface finishing was obtained from the manufacturer, the analysis of the IR spectrum of coatings was conducted to determine the credibility of the data. The same method was used for surfaces where the damages occurred due to the effects of cleansing agents to determine whether these changes are of chemical or mechanical nature.

2.3 Microscopy

In order to get better insight into the quality of wood-coating system after lacquering and after its exposure to liquids (primarily cleansing agent) about 50 μm microtome sections were cut from the lacquered samples and observed under light microscope with a magnification of 10×.

2.4 Determination of the dry film thickness

Dry film thickness of the coating was determined by modern nondestructive method using an ultrasound gauge, in accordance with EN ISO 2808: 2011.

The principle of determining the thickness of the coating was based on the measurement of time needed for ultrasonic waves emitted from the surface of the probe, transported from the surface of the coating to pass to the substrate and the same path back to the transducer. Knowing that there was unevenness on the surface of the coating that can cause the errors in the reading, drop of gel (water-glycerin-based) was placed on the coating, filling the irregularities on the surface of the coating. The measurement process involves placing the probe to the surface of the coating and withdrawal of the wrapper of probe down to the contact with the sample, thus activating the emission of ultrasonic waves to the surface. Thickness of the coating was obtained as the mean value of 10 measurements (for each group of samples).

2.5 Determination of the resistance to abrasion

The abrasion resistance of lacquered samples was tested using Taber-Abraser instrument in accordance with ISO 7784-2: 1997. Abrasion resistance was presented as the number of cycles that leads to sanding of film of coating until the surface of substrate (veneer) becomes visible. The instrument consists of the stand with specimen holder and abrasive wheels that rotate on the surface of the specimen. The wheels are made from metal with a rubber layer with abrasive strips attached to it. The abrasive wheels are placed on horizontal bar, which is located above the specimen holder. Fastening of specimen to a holder is achieved by the vertical bar, which required boring of 10 mm-hole at the intersection of the diagonal of the specimen. The dimensions of holder determine the dimensions of specimen as follows: 10×10 cm. The horizontal bar with wheels was lowered until the contact of wheels and lacquered surface. Rotation of the specimen holder lead to forced rotation of the abrasive wheels, which caused wear on the surface. In order to remove particles of the coating that could affect the filling up of abrasive strips, and thus seeming to improve the abrasion resistance of the lacquered surface, the suction tube was set between the wheels.

The abrasion resistance was measured as weight loss of coating-wood system after every 20 or 100 rotation cycles (until 600 cycles) using the formula:

$$x_i = (m_0 - m_i)/b_i \cdot 1000\ (mg), i = number\ of\ rotation\ cycles$$

Where:
x_i - the loss of coating weight after a certain number of rotation cycles (mg)
m_0 - initial weight coated specimen (mg)
m_i - weight of the specimen after a certain number of abrasion cycles (mg)
b_i - number of cycles of rotation between readings

2.6 Determining the resistance to cold liquids of lacquered surfaces

Testing the resistance of lacquered surfaces to chemicals that furniture could commonly be exposed during use, is made in accordance with EN ISO 1272:2009. This standard provides determination of the resistance to liquids of lacquered surfaces using absorbing discs, made of soft filter paper with a 10 mm diameter. The filter paper was immersed in a vessel containing the test fluid, and after 30 to 60 seconds removed with the tweezers with quickly wiping off the edge of the disc once against the edge of the vessel. The filter paper was placed on the surface of the sample and covered with petri dish (40 mm-diameter and 25 mm-height). We tested the resistance oflacquered surfaces to water and to cleansing agents "OASIS PRO 40, ECOLAB GmbH, Switzerland (pH 7.6; intermediate flux evaporation from the free surface of the liquid 2.5 $g/m^2 \cdot min$). Test periods for both liquid were 1h, 6h, 16h and 24h.

2.7 Determination of resistance to cleaning of lacquered surfaces

In order to simulate the cleaning conditions that can be expected during use, testing of frequent cycles of cleaning was conducted by an accelerated test in conditions of controlled laboratory experiment. Work environment parameters were as follows: temperature 18-24˚C and relative humidity of 50-70 %. One cycles of cleaning consisted of spraying of liquid: water or “OASIS PRO 40” from a spray bottle to the test surface. The average amount of aerosols was 10 g/m^2. The wetted surfaces were wiped with 32×32 cm microfiber cloth (EKOLAB Polifix-microcline-eco), with five crosswise wipes in vertical direction and five of such wipes in horizontal direction. The surface was dried with a soft clean cotton cloth. Estimated pressure during wiping was about 25 g/cm^2.

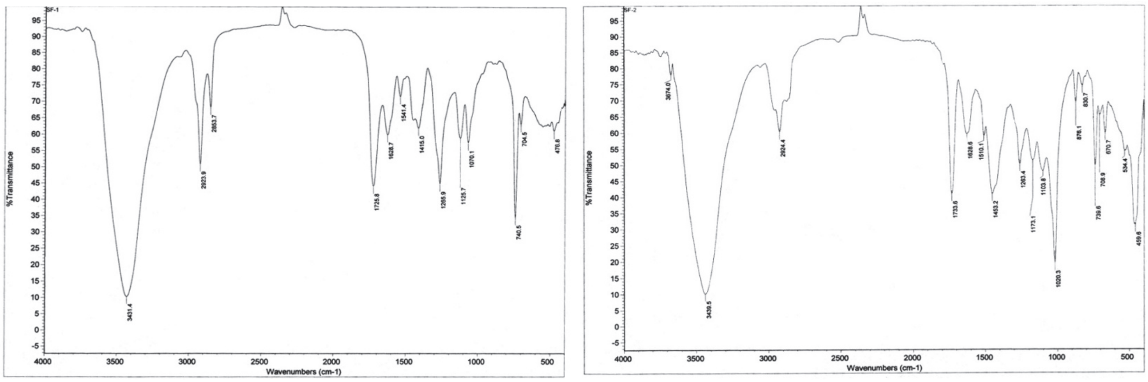
3. RESULTS AND DISCUSSION

3.1 Determining the types of coatings using IR-spectroscopy

Polyurethane coatings are characterized by absorption peak in the 1730-1720 cm^{-1} wavelength region. This peak corresponds to urethane group (R-NH-CO-OR) where strong absorbance of carbonyl group is affected by the presence of NH groups (as in normal amines) but with opposite increase in frequency due to the presence of C-O-R structure of ester groups (Bellamy, 1975).

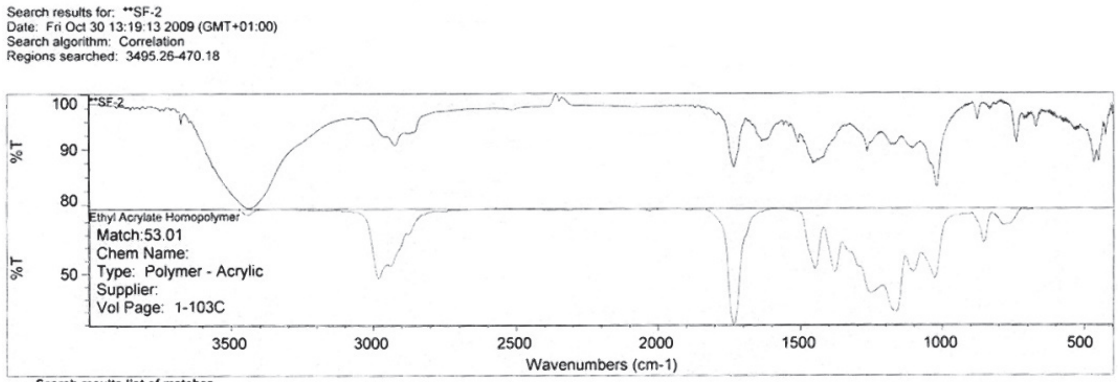
Figure 1a shows the IR absorption spectrum of coatings with peak at 1725.8 cm^{-1}. The next variant at 2923.9 and 2853.7 cm^{-1} and peaks in the "fingerprint" region at 1265.9 and 740.5 cm^{-1} correspond with the IR spectrum of two-component PU coating (Prieto and Kienle, 2007) confirming the samples of I group were lacquered with this type ofcoating.

Figure 1b shows the IR spectrum of the coating from the second group of samples. Increased carbonyl frequency at 1733.6 cm^{-1} is characteristic of acrylic polymers. In addition absorbance launched by conjugation from 1628.6, as well as absorbance at 1453.2, 1020.3 and 459.6 cm^{-1} in the "fingerprint" region, with the presence of talc, indicated the polyacrylic structure. The search algorithm for the correlation of investigated coating gave the best agreement with the acrylate homopolymer, which led to conclusion that this spectrum corresponds to PA coating containing talc (Figure 2).



a) b)

Figure 1. *IR spectrum of: a) PU coating, b) UV-PA coating*



Search results list of matches

	Index	Match	Compound Name	Library Name
1	1347	56.86	Hoover 512-BU	Coatings Technology
2	1304	56.79	Whittaker 1745 Talc	Coatings Technology
3	1345	54.12	Hoover 210-RS	Coatings Technology
4	3	53.01	Ethvl Acrylate Homopolymer	Coatings Technology
5	2080	52.98	Kelzan D	Coatings Technology
6	1766	51.07	Troysol S366	Coatings Technology
7	2152	50.62	Byk 310 Mar and Slip Agent	Coatings Technology
8	580	50.14	Talc	HR Thermo Nicolet Sampler Library
9	1830	50.11	Resiflow W	Coatings Technology
10	1738	49.59	Disperse AYD-6	Coatings Technology

Figure 2. *The correlation of the investigated coatings and acrylic homopolymers*

3.2 Dry film thickness of coating

Based on average value of 10 measurements, dry film thickness of PU and UV-PA coating was 129 µm and 58 µm, respectively.

3.3 Resistance to abrasion of lacquered surface

Figure 3 presents the results of abrasion resistance in terms of weight loss after a specified number of cycles. Visual observation showed that after 200 cycles of abrasion substrate became visible in both groups of samples, leaving the face of veneer exposed to the impact of abrasive wheels. Weight loss after 200 cycles of rotation corresponded to wood weight loss. For this reason, the chart shows the weight loss after every 20 cycles (from 1. to 200. cycles), and then after every 100 cycles (from 200. to 600. cycles). The fading of weight loss differences between the groups of samples indicated that the film of PU coating was completely removed from the surface of the samples after 200 cycles of rotation. In the case of UV-PA coating the uniformity of weight loss occurred after 160 rotation cycles. The difference in results can be related to lower dry film thickness of the UV-PA coating, and thus the lower starting weight of this group of samples, which is consistent with the conclusion of Keskin and Tekin, 2011. Also, previous studies showed that the coating formulation had an impact on the value of the resistance to abrasion (Jaić and Palija, 2012), where the higher value of resistance to abrasion of the top coat was achieved in case of PU coating, in relation to PA coating.

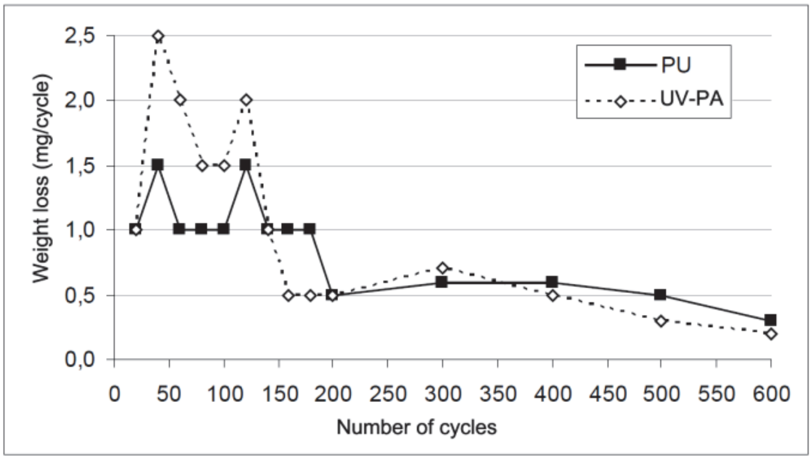
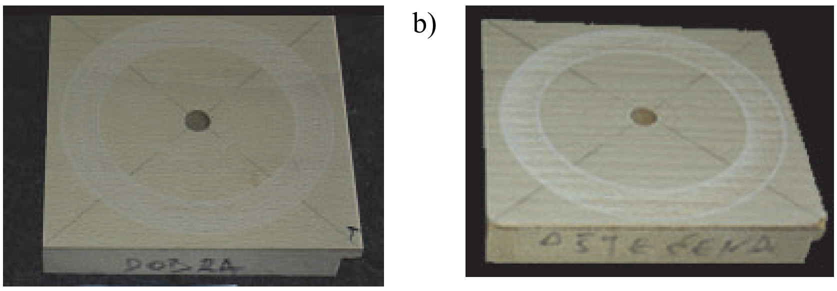


Figure 3. *The weight loss of the lacquered samples between the readings of cycles*

In Figure 4, the changes of lacquered surfaces after 160 cycles of rotation (a - I group of samples, b - II group of samples) and after 600 cycles of rotation (c - in I group of samples, d - in II group of samples) can be seen. These figures represent a visual confirmation of the measured results. After 160 cycles of rotation in samples lacquered with PU coating (4a) the film of coating was still present and white border of low visibility was seen at the boundary line between the tracks, that wheels formed, and the rest of the sample. After the same number of rotation cycles in the samples coated with UV-PA coating film was completely removed from the surface and the white pigment was intensively visible on the entire surface of abrasion action. The difference between the two groups of samples after 600 cycles of rotation was the visibility of residual white pigments in the border zone of the abrasion of samples that were coated with UV-PA coating.

a) b)



c) d)

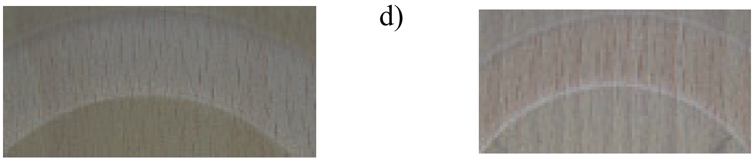


Figure 4. *a) Sample lacquered with PU coating after 160 cycles of abrasion b) Sample lacquered with UV-PA coating after 160 cycles of abrasion c) Segment of the sample coated with PU coating after 600 cycles of abrasion b) Segment of the sample coated with UV-PA coating after 600 cycles of abrasion.*

The weight loss of UV-PA coating was significantly higher than the weight loss of PU coating, particularly at the initial stage of abrasion (the weight loss of UV-PA coating was by 67 % higher than the weight loss of PU coating after 40 cycles of rotation). Knowing that changes in the surface layer of coating can significantly reduce the aesthetic quality of lacquered surfaces, weight loss in initial stage of abrasion is extremely important.

3.4 Resistance to cold liquids of lacquered surfaces

Table 2 shows the results of measurement of resistance to water and cleansing agent of both groups of samples after a certain test periods.

Table 2. *Evaluation of resistance of surfaces lacquered with PU coating and surfaces lacquered with UV - PA coating to activity of water and cleansing agent*

Test period (h)	PU coating		UV-PA coating	
	OASIS PRO 40	Water	OASIS PRO 40	Water
1	5	5	4	5
6	5	5	4	5
16	5	5	3	4
24	5	5	2	4

Where assessment shows the following defects:

5 - no change; test area indistinguishable from adjacent surrounding area;
4 - minor changes; discoloration and change of gloss visible at a certain angle ofobservation;
3 - moderate changes; test area distinguishable from adjacent surrounding area, visible in several viewing directions;
2 - significant changes; test area clearly distinguishable from adjacent surrounding area, visible in all viewing directions;
1- strong change; the structure of the surface being distinctly changed.

3.5 Resistance to cleaning of lacquered surfaces

Table 3 shows the number of cleaning cycles, which led to damages that were visible to the naked eye. The samples coated with PU coating showed no signs of damage after 150 cycles of cleaning with water or cleansing agent. The samples coated with UV- PA coating showed lower resistance to cleaning, where more "aggressive" cleansing agent in relation to water led to the faster development of damage.

Table 3. *The changes of the lacquered surfaces after accelerated cyclic cleaning*

Type of coating	PU coating		UV-PA coating	
Cleansing liquid	OASIS PRO 40	Water	OASIS PRO 40	Water
Number of cycles when demages became visable	No damages after 150 cycles	No damages after 150 cycles	96	149

3.6 Characterization of the damages on lacquered surfaces

The visible damages included the initial damages of UV-PA coating in form of white marks with 1 mm diameter. White color of flecks that were formed in the process of cleaning of UV-PA coating was result of the talc presence and /or sub-layers of white pigment used for coloring the veneer. In addition, the corrugated (wavy) and rough places which resulted from the raising of the UV-PA coating were observed on damage surfaces. Microscopic observation of the samples before and after the cleaning with cleansing agent indicated differences in homogeneity of the film coating in II groups of samples. While the film of the coating in I group of samples was homogenous and compact after cleaning procedure (Figure 5a), liquid caused the degradation of homogeneity of the film in II group of samples, which led to successive changes in the structure of the coating and the surface of the veneer. In the initial stage the cleaning caused decomposition of the coating and some parts of the surface became "stripped" i.e. unprotected (Figure 5b). On these places, veneer was exposed to a cleansing agent, which led to the raising of the wood fibers. The initial process of destruction of the wood-coating system continued with mechanical action of wiping (by cloth), which led to further raising and separation of wood fibers from the surface of the sample (Figure 5c).

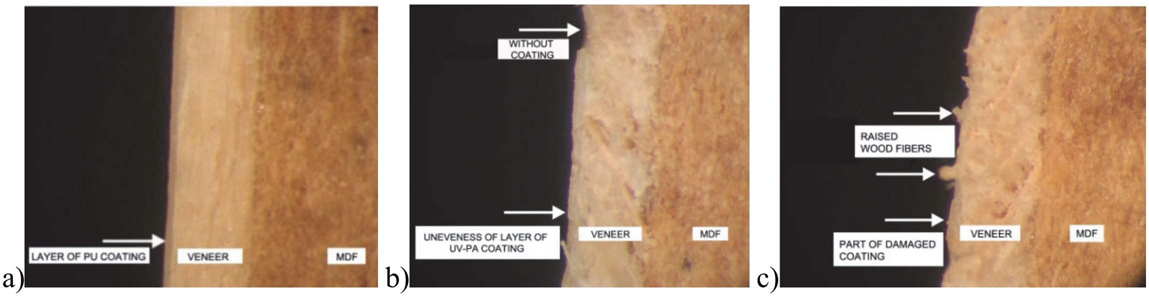


Figure 5. *Microscopic section of lacquered samples: a) sample lacquered with PU coating, b) and c) the sample lacquered with UV-PA coating after cleaning*

The comparison of the IR spectra of UV-PA coating before and after the cleaning cycle showed that there was a difference between them. The difference is reflected in the disappearance of peak 1628.6 cm^{-1} in the damaged coating; peak shift from 1453.2 to 1439.2 cm^{-1} and increase of its intensity, moving of weaker peak from 1263.4 to 1250 cm^{-1} and the disappearance of peaks at 739.6 and 708.9 cm^{-1}, also in the damaged coating (Figure 6). This indicates that the changes, which occurred during cleaning of surfaces coated with UV-PA coating, were of chemical nature.

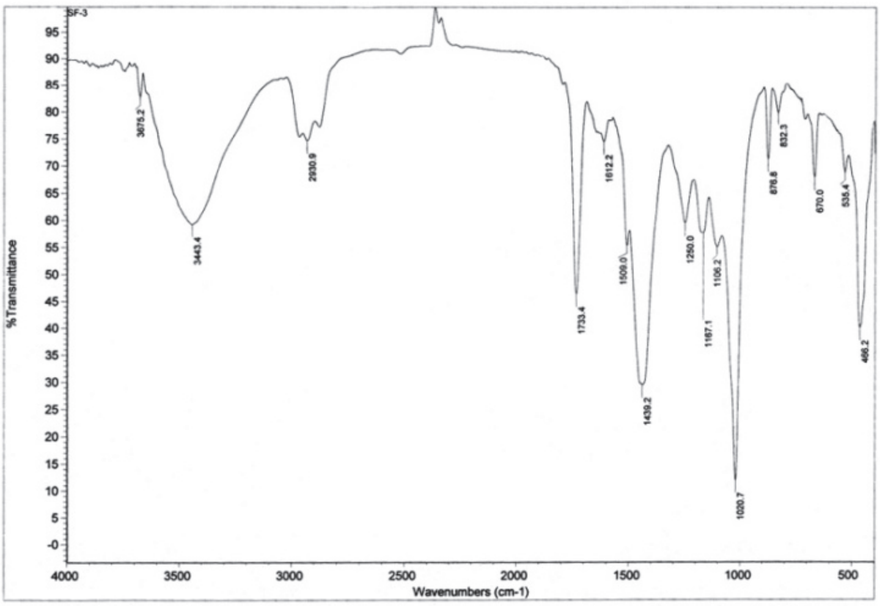


Figure 6. *IR spectrum of samples lacquered with UV -PA coating after cleaning cycles*

4. CONCLUSIONS

Application of IR spectroscopy confirmed that the samples of I group were lacquered with PU coating, while the samples of II group were lacquered with PA coating.

The samples of stained MDF boards lacquered with PU coating showed significantly greater resistance to abrasion and resistance to cold liquids, compared to stained samples of MDF boards lacquered with UV-PA coating. For the II group of samples (UV-PA coating) sanding through the film of coating and visibility of veneer occurred after 160 rotation cycles of abrasive wheels. For the samples of I group (PU coating) substrate became visible after 200 rotation cycles of abrasive wheels. The difference in abrasion resistance and resistance to liquids of samples coated with PU and UV-PA coating could be related to the difference in the formulation of coatings, and the difference in the dry film thickness, since the samples coated with PU coating showed significantly higher dry film thickness (129 µm) compared to the samples coated with UV-PA coating (58 µm). The difference in the dry film thickness of coating was in accordance with the application method (PU coating was applied by spraying, while UV-PA coating was applied by roller machine).

Application of cleansing agents in the samples lacquered with UV- PA coating led to damage in form of white marks. These damages were of chemical-mechanical nature and they present the result of the decomposition of coating by effects of liquid agents (phase I) and further mechanical degradation of the coating due to effects of abrasion procedure (rubbing with a cleaning cloth), with raising and separation of fibers from the wood substrate (phase II).

The presence of talc in the formulation of UV-PA coatings that was detected by IR spectroscopy indicates that the share of resins (binder) in solid contents of the coating is reduced by amount of filler, which could have a significant impact on values of properties of lacquered surfaces.

With application of standard cleaning system with using of cleansing agent ("OASIS PRO 40") it can be expected for damages on the samples lacquered with UV-PA coating to occur after just 3 to 3.5 months of the beginning of the use. By using plain water for cleaning of furniture lacquered with the same type of coating, the appearance of damages can be expected after 5 months.

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EXPLORING THE ENERGY PERFORMANCE OF INDUSTRIAL AND LABORATORY PRODUCED PELLETS

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ABSTRACT

This article presents the methodology and results of experimental testing of the calorific value and ash content of industrial and laboratory produced pellets. Studies were conducted in the Department of Forest Harvesting, Logistic and Amelioration of the Technical University in Zvolen.

Key words: pellets, calorific value, ash contents

1. INTRODUCTION

The main reason for the production of refined fuels from woody biomass (dendromass) is the need to adapt the raw material in a form that is most suitable for combustion technologies. Furthermore, the production of these fuels is associated with better transportation security and maximum use of the energy potential of biomass.

Pellets are among biofuels produced from wood chips and sawdust, without adding binders. Their density reaches approximately to about 1,4 $t.m^{-3}$ and thermal value of 17 to 21 $MJ.kg^{-1}$. This is fuel that meets the highest standards of comfort and the ability to automate the process of heating; this had a positive impact on the environment. The heat obtained from the combustion of a unit mass of pellets is expressed through their caloricity.

The purpose of this paper is an experimental study of the energy performance of industrial and laboratory produced pellets.

2. MATERIAL AND METHODS

The methodology of experimental studies is determined by the equipment used respectively: liquid calorimeter or calorimetric bombs (with exploding burning) (Lunguleasa, 2009).

In the laboratory of the Department of „Forestry Harvesting, Logistics and Ameliorations” in Techical University in Zvolen, R. of Slovakia were examined calorific value of laboratory-produced pellets (Pellet sample №3), made from willow (Salix viminalis), obtained from the experimental energy plantation near the village Hrabiny in Slovakia (Figure 1A), as well as industrial pellets produced by two companies in Bulgaria: Pellet sample №1 and Pellet sample №2 (picture 1B).

Samples were prepared in accordance with Slovak standard STN 44 13 52 - *Determination of the heat combustion and calculation of calorific value*.

The sequence of work includes the following phases:

❑ Fragmentation of raw material for pellets (willow - *Salix viminalis*) and drying in universal oven, model "*Memmert*" (Germany) to constant weight at $104^{\pm 2}$ ^{0}C (Figure 2A):

- weight in the wet state 839,24 g;
- weight in the dry state 820,85 g.

A B

Figure 1

- Fragmented and dried material is placed in a special ring (picture 2B) and using the screw press (Figure 3A) is prepared pellets (Figure 3B).

A B

Figure 2

❑ The ring is weighed with and without pellet using an analytical balance with auto calibration, model "*ALT 160-4NM*" (UK), with accuracy ± 0,01 g (Figure 3C and 4A). Measuring range from 0,1 mg to 160 g:

✓ weight of the ring 10,3741 g (Figure 3C);
✓ weight of the ring with pellet 11,5512 g (Figure 4A);
✓ weight of the pellet 1,1771 g.

A B C

Figure 3

- The ring with pellet is placed on a stand (Figure 4B) with two electrodes and put a fuse (Figure 4C). The calorific value is based on the standard STN 44 13 52 and the procedure specified by the manufacturer of the oxygen bomb calorimeters.

A B C

Figure 4

- The ring with pellet and both electrode with fuse (Figure 4C) are placed in calorimetric bomb (Figure 5A). Calorimetric bomb is placed in filling station for oxygen (O_2), for 30 s, at a pressure of 34 bar (Figure 5B).

A B C

Figure 5

- Calorimetric bomb is placed in an adiabatic calorimeter, model „*IKA C200*” (Germany) (Figure 5C and 6A). It consists of measuring chamber – „*C 200*”, decomposition vessel – „*C 5010*” and filling station for O_2 - „*C 5010*”. In calorimeter pour 2 *l* H_2O, as the initial temperature of the water should be 20÷25 ^{0}C (Figure 6B). Wait 15÷17 min, the temperature indicated on the display every minute. Ignition and calculation of gross calorific value is performed automatically using specialized software "*C5040 Calwin*" for controlling the calorimeter and administration of the measured data (Figure 6C). Possible transfer and recharge Excel or Word.
- In specialized software sets the weight of pellet and heat of 50 J to fuse (Figure 6C). The results are reported to the Protocol.

3. RESULTS AND DISCUSSION

The Protocols of the measurements are presented below: Pellet samples №1, №2 and №3. The protocol consists of three parts:

1. Determination of relative humidity.
2. Determination of burning heat and calorific calculate of the pellets.
3. Determination of ash content.

To determine the heat of combustion is necessary to determine the heat capacity of the calorimetric systems. Weighed sample is placed in contact with the combustion wire. Then it is placed in a bomb calorimeter, where it is burned in pure oxygen under a pressure of 30 bar.

A B C

Figure 6

Combustion of the sample is ignited electrocution. The resulting heat will increase the temperature the calorimetric system. After about 10 to 15 minutes after ignition, the heat exchange between the ends calorimetric bomb and the water that surrounds it in internal boiler. Measure the temperature rise and the temperature difference is used to calculate the heat of combustion. Calculate the heat of combustion determined under adiabatic conditions, according STN 44 13 52 based on the formula (Lieskovský, Suchomel and Gejdoš, 2009):

$$Q_s^a = \frac{C(t_n - t_o) - c}{m} \qquad (1)$$

Where

Q_s^a is a heat of combustion, MJ.kg^{-1};
C – heat capacity of the calorimetric system, J.^{0}C^{-1};
t_0 – final temperature of the first section, ^{0}C;
t_n – final temperature of the main section, ^{0}C;
c – total correction, J;
m – mass of measured analytical sample of fuel, g.

Fresh dendromass always contains a certain proportion of water, which reduces the effective calorific value compared with a gross calorific value. Fuel efficiency is calculated according to the formula:

$$H_W = \frac{H_S(100 - w) - r.w}{100} \qquad (2)$$

Where

H_W is actual fuel efficiency, MJ.kg^{-1};
H_S – heat of combustion, ie calorific value in dry state, MJ.kg^{-1};
w – percentage of moisture in the fuel, %;
r – the heat required to evaporate 1 kg of water from the wet material, 2,44 MJ.kg^{-1}.

The results of the protocols show that:

- relative humidity of the pellets is respectively: in protocol № 1 – 7,2%, № 2 – 8,1%, № 3 – 11,3%;
- heat of combustion: in protocol № 1 – 19,432 MJ.kg^{-1}, № 2 - 20,068 MJ.kg^{-1}, № 3 – 20,597 MJ.kg^{-1};
- calorific value of the pellets for moisture 0% is: in protocol № 1 – 18,090 MJ.kg^{-1}, № 2 – 18,726 MJ.kg^{-1}, № 3 – 19,255 MJ.kg^{-1};
- calorific value of the pellets as supplied is: in protocol № 1 – 16,609 MJ.kg^{-1}, № 2 – 17,021 MJ.kg^{-1}, № 3 – 16,797 MJ.kg^{-1};
- ash content of the pellets in weight: in protocol № 1 – 0,99; № 2 – 1,37; № 3 – 2,84.

PELLET SAMPLE № 1

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PROTOCOL OF MEASUREMENTS № 1

Sample taken on 11.09.2012

1. Determination of relative humidity

Relative humidity measured by the method of drying

Weight of wet sample [g]	353,69
Weight of dry sample [g]	331,36
Mass measuring cup [g]	44,25
Mass of water [g]	22,33
Dry weight [g]	287,11
Measured relative humidity [%]	7,2

2. Determination of burning heat and calorific calculate

Weight of wet sample [g]	1,2322
Burning heat [MJ.kg^{-1}]	19,432
Calorific value [MJ.kg^{-1}] according to ÖNORM M 7132 for moisture 0%	18,090
Calorific value [MJ.kg^{-1}] according to ÖNORM M 7132 as supplied	16,609
Calorific value [MJ.kg^{-1}] according to ISO 1928 as supplied	16,717

3. Determination of ash content

Weight of the empty bowl [g]	31,5901
Weight of the bowl with tested sample [g]	35,5849
Weight of the bowl with ashes [g]	31,6296
Sample weight [g]	3,9948
Weight of ash [g]	0,0395
Ash content in weight percent	0,99

PELLET SAMPLE № 2

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PROTOCOL OF MEASUREMENTS № 2

Sample taken on 11.09.2012

1. Determination of relative humidity

Relative humidity measured by the method of drying

Weight of wet sample [g]	183,60
Weight of dry sample [g]	172,57
Mass measuring cup [g]	44,37
Mass of water [g]	11,23
Dry weight [g]	128,20
Measured relative humidity [%]	8,1

2. Determination of burning heat and calorific calculate

Weight of wet sample [g]	1,1512
Burning heat [MJ.kg^{-1}]	20,068
Calorific value [MJ.kg^{-1}] according to ÖNORM M 7132 for moisture 0%	18,726
Calorific value [MJ.kg^{-1}] according to ÖNORM M 7132 as supplied	17,021
Calorific value [MJ.kg^{-1}] according to ISO 1928 as supplied	17,130

3. Determination of ash content

Weight of the empty bowl [g]	34,9026
Weight of the bowl with tested sample [g]	37,5145
Weight of the bowl with ashes [g]	34,9383
Sample weight [g]	2,6119
Weight of ash [g]	0,0357
Ash content in weight percent	1,37

PELLET SAMPLE № 3

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PROTOCOL OF MEASUREMENTS № 3

Sample taken on 11.09.2012

1. Determination of relative humidity

Relative humidity measured by the method of drying

Weight of wet sample [g]	316,19
Weight of dry sample [g]	285,90
Mass measuring cup [g]	44,14
Mass of water [g]	30,89
Dry weight [g]	241,76
Measured relative humidity [%]	11,3

2. Determination of burning heat and calorific calculate

Weight of sample [g]	1,4514
Burning heat [MJ.kg^{-1}]	20,597
Calorific value [MJ.kg^{-1}] according to ÖNORM M 7132 for moisture 0%	19,255
Calorific value [MJ.kg^{-1}] according to ÖNORM M 7132 as supplied	16,797
Calorific value [MJ.kg^{-1}] according to ISO 1928 as supplied	16,907

3. Determination of ash content

Weight of the empty bowl [g]	35,2103
Weight of the bowl with tested sample [g]	37,6178
Weight of the bowl with ashes [g]	35,2786
Sample weight [g]	2,4075
Weight of ash [g]	0,0683
Ash content in weight percent	2,84

4. CONCLUSION

The analysis of the studied Bulgarian pellets shows that:

1. Pellets of Protocol № 1 have better performance because:

- relative humidity of pellets in Protocol №1 is 12,5% less than those of Protocol №2;
- the heat necessary to burn the pellets in Protocol №1 is 3,3% less than those of Protocol №2;
- calorific value of pellets in Protocol №1 with 0% humidity is 3,5% higher than those of Protocol №2;
- calorific value of pellets in Protocol №1 in delivered state was 2,5% higher than those of Protocol №2;
- ash content of the pellets in Protocol №1 is 38% lower than those of Protocol №2.

2. Calorimetric analysis of indicators of pellets from willow (Salix viminalis), obtained under laboratory conditions showed that:

- its relative humidity is higher;
- need a higher heat burning;
- calorific value at 0% humidity is higher if you compare them with pellets fromy Bulgarian producers, but lower in the delivered condition;
- ash content is significantly higher due to the high content of bark that was not removed.

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INVESTIGATION OF THE NATURAL FREQUENCIES AND THE MODE SHAPES OF THE CIRCULAR SAW USING FINITE ELEMENTS METHOD. PART I: MECHANIC-MATHEMATICAL MODEL

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ABSTRACT

This study focuses on an adequate mechanic-mathematical model for investigation of free vibrations of a circular saw. The model presents features in the construction of a kind of circular saws. It also gives an opportunity to make simulative investigations which can be used for studying circular saw's natural frequencies and mode shapes. The research is done by the Finite element method. As a result this study allows the determination of the resonant regimes. The determination of these regimes is important for introduction of adequate measures which can guarantee their using. It directly influences the reliability of the machine as well as the accuracy and quality of the production.

Key words: circular saws, modelling, vibrations

1. INTRODUCTION

The level of the vibrations and the noise during the work of modern woodworking machines is one of the main indicators which can be used for evaluation of this kind of machines. It is necessary to study the essence of processes that are typical for the machine to find out reasons for the appearance of the vibrations and the noise. It is also necessary to make some investigations in order to present each element as a mechanical vibration system with some characteristics (Minchev and Grigorov, 1998).

Some methods for influence on the vibration system must be formulated in order to be used in the fight with harmful vibrations. It leads to introduction of accurate requirements connected with the construction and the work of its elements. Therefore, formulation and analysis of the equations which describe the vibrations of the elements of the woodworking machines, is very important. These equations can be used as a base for investigations and giving recommendations to the construction and the way of its work (Veits, Kochura and Martinenko, 1971).

The circular machines are among the machines whose work is accompanied by vibrations and noise (Obreshkov, 1996; Filipov, 1977). Figure 1 shows a format circular saw machine and a scheme of this machine (Vukov, Gochev and Slavov, 2010). The electric motor is presented by *1*, *2* is a belt gear, *3* – work table, *4* – the main shaft, *5* – the machine's body, *6* – the carriage, *7* – the treated detail, *8* – the circular saw with the flanges and nut of the main shaft.

The study of vibrations in a circular saw is especially interesting for the engineering practice in circular machines. Modern circular saws (Figure 2) are made of high-quality steels with excellent mechanical characteristics. Hard alloy plates made of special materials are included in the construction of circular saws to increase their wear proof. They are soldered to the saw body and provide reliability during its work as well as quality of the product. The high accuracy of the shape and measures is an obligatory condition for a circular saw's production. This condition means using of modern (mainly laser) technologies for the instrument processing.

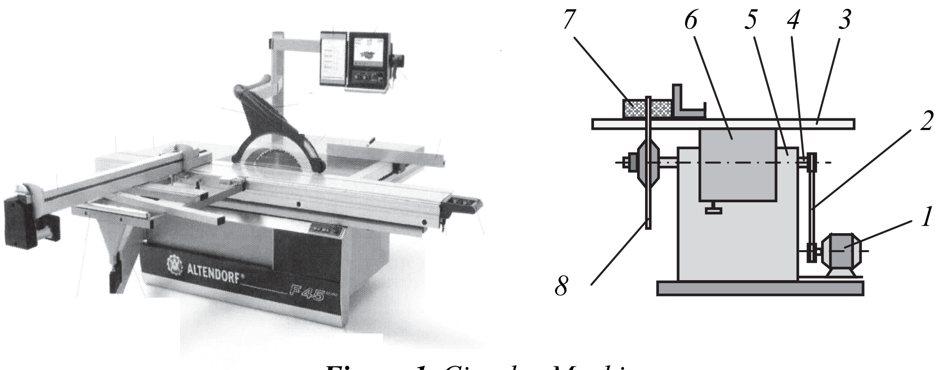

Figure 1. *Circular Machine*
1 – Electric Motor, 2 – Belt Gear, 3 – Work Table, 4 – Main Shaft,
5 – Machine’s Body, 6 – Carriage, 7 – Treated Detail, 8 – Circular Saw

Modern materials and technologies allow producing of high-quality circular saws. These saws are a base for intensive work as they allow using higher speed during the cutting. But except the advantages this process has some problems which are connected with significant centrifugal forces, heating caused by friction between the disc and the wood, increase of vibrations and noise. It requires extra investigations of this kind of saws.

Figure 2. *Circular saw*

As every mechanical vibration system, the vibration characteristics of the circular saw have their natural vibration frequencies. When the frequencies of the external influences which caused vibrations are equal to a frequency of their natural frequencies appears phenomenon “resonance”. Resonance regimes can lead to significant increase of vibration amplitudes. Significant vibration amplitudes change the normal work regimes of the machine and damage the accuracy and quality of the production (Vukov and Georgieva, 2009; Marinov and Vukov, 2004). Extra stress, which is caused by increase of vibration amplitudes, sometimes can reach such values that can damage or even destroy some machine’s elements (Marinov and Vukov, 2009).

It is necessary to make preliminary evaluation of the danger, caused by resonance, in designing and dimensioning of circular machines. Therefore it is necessary to study the natural frequencies of the circular saw’s vibrations. If there is a resonance danger, some changes in the construction have to be done.

The aim of the study is to build an adequate mechanical-mathematical model for investigation of free vibrations of a circular saw, concerning characteristics in its construction. Some simulative investigations can be made on this base and these investigations can help to define resonance regimes and to formulate some requirements to avoid them.

Studying of the dynamical processes in circular machines and in their elements is based on the current CAD systems for 3D design and investigation. The main advantage of these systems is the programme core for simulative investigations of the developed models. It is necessary to include estimation by the Finite element method as a base for the investigations. It is known that this method gives reliable numerous algorithms for analyzing of the technical construction. It can be used as a universal mean for estimation and analysis of the behaviour of the circular machines' elements when there are various force and heat loads. It can also be used for solving problems connected with a high level of the noise in these machines. 3D (volumetric) or 2D (surface) finite elements are used practically for static, dynamic, kinematic engineering analysis. Therefore, it becomes possible to determine the natural frequencies, to foresee the material fatigue, its heat conduction, plastic deformations and etc.

The current engineer practice shows that in cases, when it is necessary to model vibration and acoustic state of the system, it is very perspective to use dynamical modelling by the Finite element method.

As it has already been said, when act disturbances whose frequencies are equal to some of circular saw's natural frequencies, resonant vibrations appear. These vibrations have big amplitudes and higher levels of noise that accompanies the work of the machine. Principally resonant effects are unwilling. They can be avoided by a suitable selection of parameters of the circular saw and other details and units in the mechanical system (Amirouche, 2006; Coutinho, 2001). To solve this problem it is necessary to make adequate simulative studies in advance.

2. MECHANIC-MATHEMATICAL MODEL

The circular saw, drawn in 3D by the application programme Solid Works [13], is shown on the figure 3.

The figure 4 shows the mesh of four node 3D finite elements, modeled by the application programme Cosmos Works.

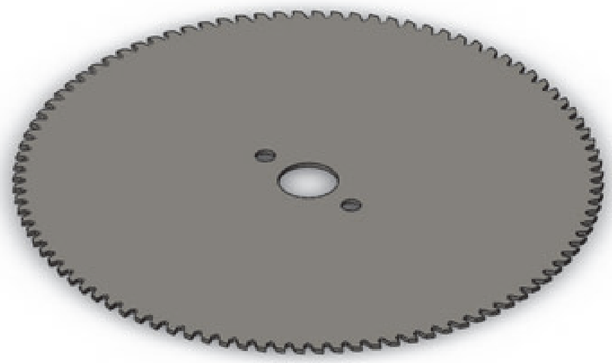

Figure 3. *Circular saw, drawn in 3D space*

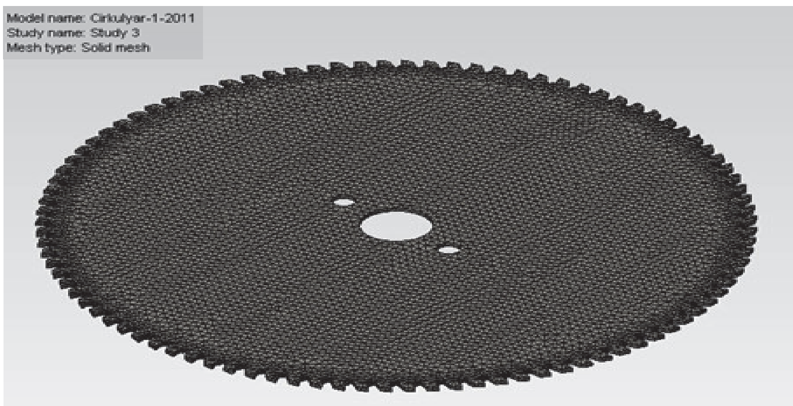

Figure 4. *Circular saw, modelled by the mesh of finite elements*

The investigation of the vibrations of the circular saw requires formulation and solution of the differential equations which describe these processes. Therefore, it is used the matrix mechanics (Angelov, 2010; Angelov and Slavov, 2010).

The differential equations which describe the free continuous vibrations of the circular saw are

$$\mathbf{M}.\ddot{\mathbf{q}} + \mathbf{C}.\mathbf{q} = 0, \tag{1}$$

where:

$\mathbf{q} = [q_1 \quad q_2 \quad \ldots \quad q_n]^T$ is the vector of the generalized coordinates; (2)

$\mathbf{M}$ – the matrix, which characterizes the mass-inertial properties of the mechanical system;

$\mathbf{C}$ – the matrix, which characterizes the elastic properties of the mechanical system.

The system of connected linear differential equations is obtained when the vibrations are small.

Particular solutions of the system of the differential equations (1) are searched as:

$$\mathbf{q}_r = h_r.\sin(\omega_r.t + \varphi), \tag{3}$$

Where h_r is the amplitude of the small vibration on the generalized coordinate q_r with natural frequency ω_r, and φ is initial phase.

After differentiation of (3) and substituting in (1) it is obtained a system of linear algebraic equations:

$$\left| \mathbf{C} - \omega^2.\mathbf{M} \right| . \mathbf{V} = 0. \tag{4}$$

To determine the natural frequencies and the mode shapes, it is necessary to solve the task about finding of the natural values and the natural vectors of the equations (4). The satisfactory of the equations (4) requires the follows:

$$\det\left(\mathbf{C} - \omega^2.\mathbf{M}\right) = 0. \tag{5}$$

The roots of the characteristics equation determine the natural frequencies. The natural frequencies form the matrix of the natural values. It is:

$$\omega = diag\left[\omega_{r,r}\right], \quad r = 1,2,\ldots n. \tag{6}$$

The natural frequencies are determinate by (6):

$$f_r = \frac{\omega_{r,r}}{2.\pi} \ Hz. \tag{7}$$

The natural values of the system (5) determine the natural vectors. The modal matrix of the free vibrations is determined by the equations (4) and (5):

$$\mathbf{V} = \begin{bmatrix} V_{11} & V_{12} & \ldots & V_{1n} \\ V_{21} & V_{22} & \ldots & V_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ V_{m1} & V_{m2} & \ldots & V_{mn} \end{bmatrix} \qquad i = 1\ldots m; \quad j = 1..n, \tag{8}$$

Where V_{ij} are the unknown amplitudes of the nodes' moving by free vibrations.

The natural frequencies and the mode shapes are determined by the known matrix, which characterizes the mass-inertial properties and the matrix that characterizes the elastic properties of the mechanical system.

3. RESULTS

The investigated circular saw is drawn in 3D by the application programme Solid Works and is modelled with the mesh of four node 3D finite elements. The model allows rendering of account the physic - mechanical characteristics of the materials and estimating the natural frequencies and the mode shapes of the circular saw by using the application programme Cosmos Works.

4. CONCLUSION AND FUTURE INVESTIGATIONS

The study shows the developed mechanic-mathematical model for investigation of free vibrations of a circular saw. The model takes into account typical characteristics in the construction of a class of circular saws. On the base of the model it is possible to make simulative investigations which can be used in studying the natural frequencies and the mode shapes of this class of circular saws. These investigations are an object of the next part of this study.

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RATE OF SORPTION OF THERMALLY TREATED BEECH (*FAGUS MOESIACA C.*) WOOD

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ABSTRACT

Dependance of sorption for thermally treated and beech (*Fagus mosesiaca C.*) wood was analyzed in this paper. In this study, the effects of three different temperatures at two different relative humidity levels were investigated. The temperatures were 170, 190, and 210 ^{0}C for 4h, and the relative humidity levels were 65% and 100%. The results indicated that wood sorption decrease as well as along with temperature increase. The same investigated procedure was conducted for the sapwood and the red heartwood. It was determined that there was a significantly higher influence of temperature on sorption for sapwood compared to red heartwood at relative humidity of 65%, and that there was no significant difference in sorption between sapwood and red heartwood at relative humidity of 100%. It was also established that density of both sapwood and red heartwood decreases with the rise of temperature, i.e. that there is an inverse density-temperature correlation.

Key words: beech wood, sorption, thermal treatment, sapwood, red heartwood

1. INTRODUCTION

Around twenty years ago thermally modified wood production began, primarily in order to increase the utility value of aesthetically less valuable tree species. This is achieved by increasing aesthetic properties that are manifested in dark colour after thermal modification. Together with these wood exposures to temperatures over 160^{0}C, wood significantly reduces its hygroscopicity compared to wood which has not undergone the heat treatment. The main cause of the decreased hygroscopicity is the destruction of hydroxyl (OH) groups, primarily in hemicellulose, which participates in the cell wall structure of wood. Longer exposure to high temperatures on this wood contribute to cross-links between hydroxyls groups in microfibrils, which further reduces its affinity for adsorption of moisture from the air. Also replacement of the hydroxyl group of the hydrophilic oxygen-acetyl groups occurs. At the same time, thermal treatment of wood at these temperatures decreases its density, and contributs to the decrease of this change and most of its mechanical properties, for example compressive and bending strength (Gunduz et al., 2008, Viitaniemi, 1997., Santos, 2000). In addition to reducing hygroscopicity of wood by heat treatment, due to the previously mentioned hydroxyl groups reduction of and the likelihood of infection lignocol fungi, increasing the durability of wood if it when is used for a products that are exploited in the exterior (house facades, windows and external doors, park furniture, gears and equipment for children's playgrounds and the like).

As a result, the primary area of application, in addition to the already mentioned product in the exterior and the interior thermally modified wood is used for products where there is great importance of its increased dimensional stability such as: flooring, panelling, kitchen furnishing, and interiors of bathrooms and saunas (Waldiner et al. 2009, Molinski et al., 2010, Jun Li Shi et al, 2007)

It can be concluded that the main objectives of thermal modification of wood are:

- reducing of hygrosopicity,
- increase od wood's dimensional stability,
- improving its aesthetic qualities,

- extension of biological life during service.

The aim of our study was to determine how heat treatment affects the rate of sorption of thermally treated beech wood (*Fagus moesiaca, C.)*. Compared density changes of thermally treated wood is something we have considered, because a previous study (Santos 2000) suggested that these change of mechanical properties of wood and are in direct correlation with the density of the wood.

2. MATERIAL AND METHODS

Specimens of beech (*Fagus moesiaca,C.)* for this study were cut from lumber whose origin is from the mountain Goč. We have cuta total of 240 specimens with measures 20 x 20 x 20 mm and divided them into 16 groups of 15 pieces in a way that is shown in Table 1.

Table 1.*Plan of experiment*

		Temperature (^{0}C)			
		Untreated	170	190	210
Sapwood	RH/N*	65/15	65/15	65/15	65/15
	RH/N	100/15	100/15	100/15	100/15
Red heartwood	RH/N	65/15	65/15	65/15	65/15
	RH/N	100/15	100/15	100/15	100/15

* RH – Relative humidity at 20 ^{0}C (%), N – Number of specimens

After cutting, 60 specimens were control group (untreated), while the rest (180) were treated at temperatures 170^0, 190^0 and 210^{0}C, respectively. After that, the specimens were dried to oven-dry conditions using standard oven-dry method and then we measured their dimensions and weight. Dimensions were measured by a digital nonius meter with the accuracy of floating 1/100 mm, and the weight was measured on an electronic analytical scale, accuracy of 0.01 g.

Half of the total number of specimens were placed in a plastic container above the supersaturated solution of salt $NaNO_3$, which provided for the relative humidity at room temperature of the air conditioning of 65%, and the other half in another plastic container above the water, which was keeping the relative humidity at room temperature of the air conditioning by 100%. During conditioning containers were sealed. Layout container for air conditioning is shown in Figure 1

To calculate the moisture content of specimens we used the standard formula:

$$MC=\frac{m_v\text{-}m_0}{m_0}*100(\%)$$

where: MC – moisture content (%), m_v – mass of wet sample (g), m_0 -mass of oven-dry sample (g).

Figure 1. *Plastic containers for samples conditioning at RH 65% and 100%*

The wood density was calculated using the formula:

$$\rho_s = \frac{M_s}{V_s} \, (g/cm^3)$$

where: ρ_s – specimen density (g/cm^3), M_s – mass of specimen (g), V_s – specimen volume (cm^3)

3. RESULTS AND DISCUSSION

3.1 Rate of sorption

The results presented in Figure 2 show that the untreated sapwood significantly faster adsorbed moisture at RH = 65% compared with thermally modified wood, and with increasing temperature of thermal modification the rate of adsorption reduced. The same relationship is between moisture adsorption rate in the red heartwood, with what is less significant impact of high temperatures (190^0 and 210^0C) in the red heartwood compared to sapwood.

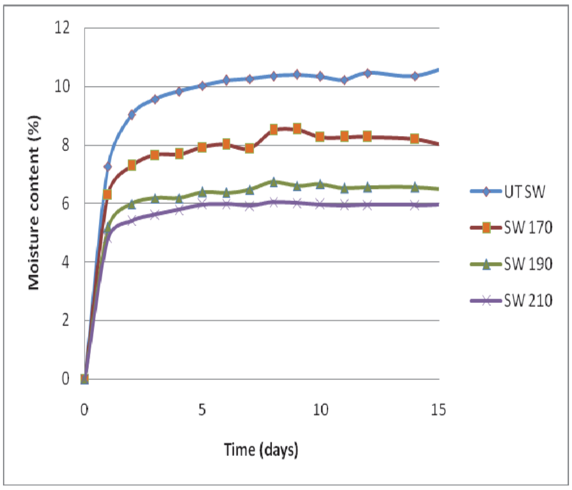

Figure 2. *Moisture content changing during time in sapwood (RH = 65%)*

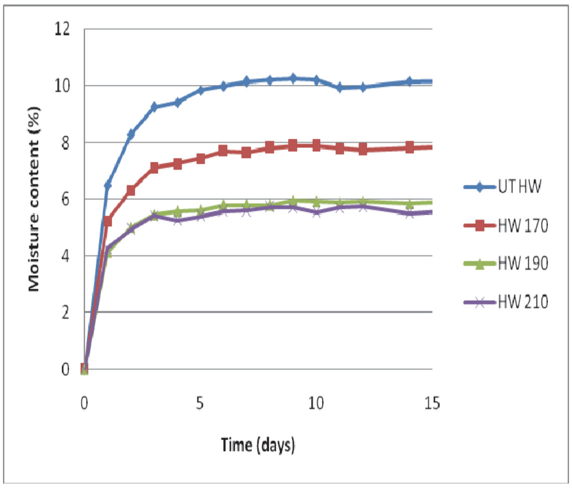

Figure 3. *Moisture content changing during time in red heartwood (RH = 65%)*

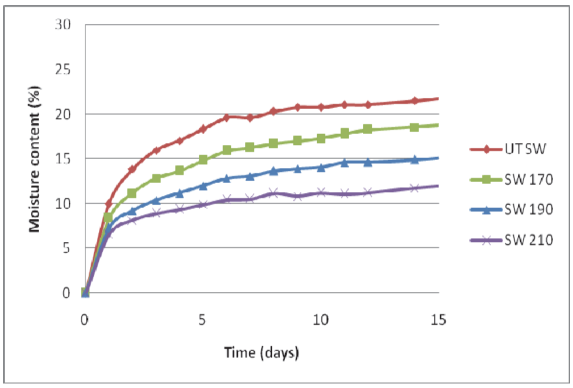

Figure 4. *Moisture content changing during time in sapwood (RH = 100%)*

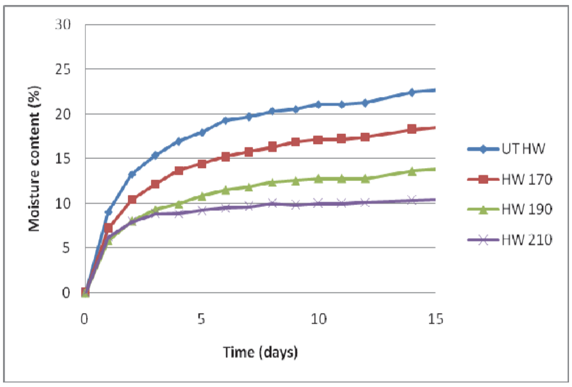

Figure 5. *Moisture content changing during time in red heartwood(RH = 100%)*

Highest rate of absorption was in the first 5 days, and then declined sharply, to eight days after the change was negligible. This statement applies to all cases, i.e. and the sapwood and red heartwood on untreated and thermally treated wood at all temperatures (Figures 2 to 5).

When we modify wood with a high temperature with increasing temperature the rate and size of sorption decrease, proving ascertainment already mentioned above that if the temperature of the thermal modification is higher, the greater number of hydroxyl groups are destroyed, and thushygroscopicity of wood is reduced.

Table 2. *Average rate of sorption for untreated and thermally modified beech wood*

RH (%) at 20 ^{0}C	Rate of sorption (%/day)							
	Sapwood				Red heartwood			
	UT*	170 °C	190 °C	210 °C	UT*	170°C	190 °C	210 °C
65	0.871	0.689	0.546	0.496	0.828	0.644	0.493	0.478
100	1.759	1.521	1.221	0.936	1.774	1.450	1.062	0.843

* UT – untreated wood

The data in Table 2 shows that at constant RH with increasing temperature significantly reduces the average speed of moisture sorption. i.e. it is the highest (at RH = 65%) in untreated wood (0.871% / day) and the lowest at a temperature of 210 ^{0}C (0.496% / day) in the sapwood.

Similar data in this study were obtained for the red heartwood and our conclusion is that there are no significant differences between the average rates of moisture adsorption between sapwood and red heartwood at the same temperatures. Data in Table 2 shows that at the RH = 100%. the average rate of adsorption in all cases nearly doubled compared to the data for the same temperature. but at RH = 65% and in the sapwood and heartwood. The results in our research is similar to those achived Callum et al. 2010.andiPoncsak et al. 2011.

3.2 Wood density changes during thermal modification

With temperature increasing. wood density decreases (Figures 6 to 9). which in our case was in the sapwood and the red heartwood at RH = 65%. and also at RH = 100%. We have come to the same conclusion as other authors in research similar to ours (Gunduz et al. 2008). The highest density of moisture content of absolutely dry wood (0%) in the sapwood was in untreated wood (0.680 g/cm^3). and lowest at the temperature of 210 ^{0}C (0.670 g/cm^3). The same. inverse. correlation is obtained during water adsorption.

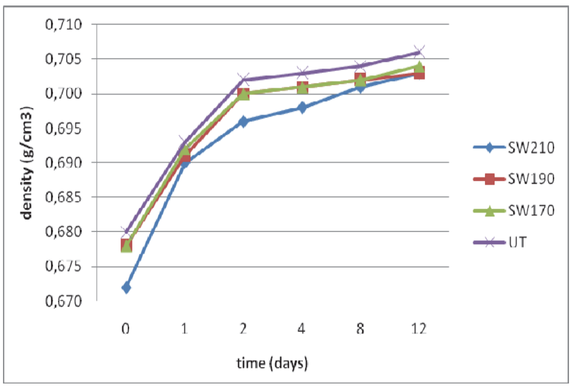

Figure 6. *Density changing of sapwood during time (RH = 65%) (UT – untreated. SW- sapwood)*

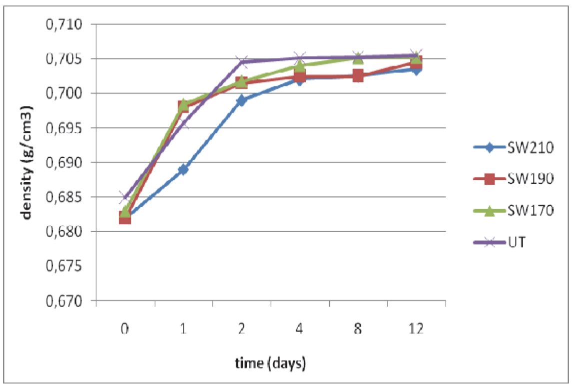

Figure 7. *Density changing o red heartwood during time (RH = 65%) (UT – untreated. HW- red heartwood)*

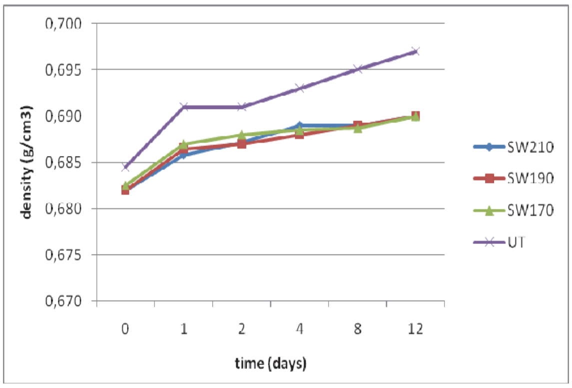

Figure 8. *Density changing of sapwood during time (RH = 100%) (UT – untreated. SW- sapwood)*

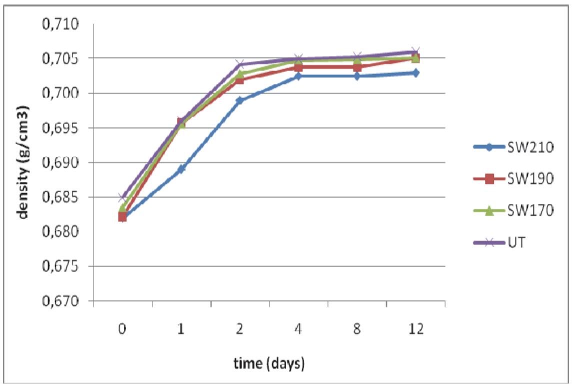

Figure 9. *Density changing of heartwood during time (RH = 100%) (UT – untreated. HW- red heartwood)*

4. CONCLUSIONS

The research results presented in this paper showed:

- Rate of absorption of untreated wood is greater compared to thermal treated wood.
- With increasing temperature. the rate of absorption reduces and reach lower values of moisture over time. The wood at higher temperatures shows lower hygroscopicity.
- Untreated sapwood and heartwood during the experiment received about the same amount of moisture. This same goes for heat treated sapwood and heartwood at a temperature of 170°C and higher.
- Increasing the temperature decreases the density of the wood and the sapwood and the heartwood.

Heartwood itself has a lower price than normal wood. This experiment has shown that thermal treatment can get assortments of sapwood and heartwood having uniform physical properties. which gives the possibility to use for making Thermowood out of heartwood.

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RESEARCH ON THE CUTTING POWER BY PROCESSING LOGS WITH HORIZONTAL BAND SAW

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ABSTRACT

In the article are discussed some of the factors which influence the cutting power by processing logs with horizontal band saw. Experimental studies were carried out in “Fagus” Ltd. manufacturing facility in the city of Pernik, Bulgaria. For performing the test was used horizontal band saw “Wirex” CZ-1/ZM (Poland). The main relationships between some factors are derived and the obtained results are analyzed.

Key words: horizontal band saw, cutting power, cutting logs

1. INTRODUCTION

The cutting power is an important indicator which characterizes the process of wood cutting.Its determination is necessary when designing new machines or change the operating conditions of already existing ones. In the literature are different methods to calculate the cutting power when cutting wood with band saw blade which are the work of different researchers such as: P. S. Afanasyev, A. L. Bershadsky, A. Z. Grube - V. I. Sanev,F. M. Manzhos etc. In its analytical determination by the different methods the obtained results are different from each other. This is due to the fact that there are a large number of unresolved issues which are related to wood processing and the associated phenomena (Genchev 1978).

The factors which influence the cutting power can be unified in three main groups:

- factors related to the cutting process;
- factors which depend on the cutting tool;
- factors which characterize the processed material.

Considering each one of them is a large task which is associated with a large number of studies (Gochev 2008, Vukov 2008). The purpose of this article is an experimental research of the influence of main factors on the cutting power: feed speed, cutting height, cutting width and wood species.

2. METHODOLOGY

Experimental studies were carried out in “Fagus” Ltd. manufacturing facility. As an experimental setup is used horizontal band saw "Wirex" CZ-1/ZM. Its cutting mechanism is shown graphically in Figure 1.

Some of the more important technical features of the machine are:

- saw wheel diameter, $D_{w.}$=600 mm;
- power of the motor which drives the leading wheel, $N_{m.}$=11 kW;
- revolutions of the motor's shaft, $n_{m.}$=24,3 s^{-1};
- diameter of the electric motor pulley;, D_1=190 mm;
- diameter of the wheel pulley, D_2=360 mm;
- feed speed U up to 0,33 $m.s^{-1}$;
- cutting speed, V=24 $m.s^{-1}$.

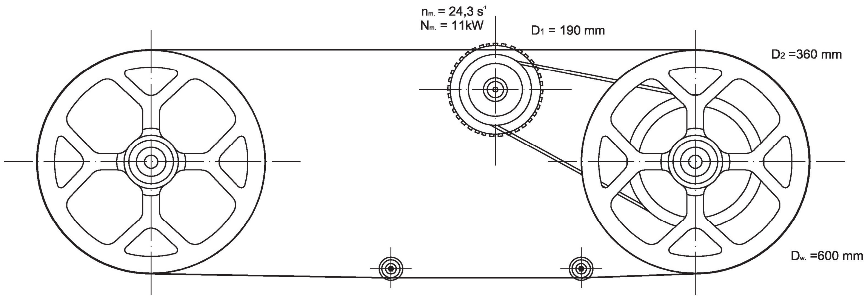

Figure 1*. Cutting mechanism – "Wirex", model 1/ZM*

The used cutting tools of the company „Carl Röntgen" (Germany) are with normal teeth. The parameters of the band saw blades are: width B=40 mm, thickness s=1,1 mm, height of teeth h'=5,5 mm, pitch t=22mm, front angle γ=10° and sharpening angle β=30°.

The cutting logs were of the following wood species: black pine (Pinus nigra) with density ρ=776 kg.m^{-3} and humidity W=39%, douglas fir (Pseudotsuga menziesii) with density ρ=545 kg.m^{-3} and humidity W=24%, beech (Fagus sylvatica L.) with density ρ=676 kg.m^{-3} and humidity W=44% and ash (Fraxinus excelsior L.) with density ρ = 777 kg.m^{-3} and humidity W = 60% (Figure 2; 3 and 4).

Figure 2. *Logs of black pine*

Figure 3. *Cutting of beech log*

Figure 4. *Cutting of ash log*

When practically determine the cutting power the following mathematical relationship can be considered with sufficient accuracy (Obreshkov 1995)

$$N_{c.}=K.b.h.U=P.V, \qquad (1)$$

Where K is specific cutting work [J.m^{-3}],

b-cutting width [m],

h-cutting height [m],

P-cutting force [N].

When cutting with such type of machines almost entirely band saw blades with part-set teeth are used. The specific cutting work is determined by the equation (Gochev 2005)

$$K = k + \frac{a_\rho . p.s}{u_z} + \frac{\alpha_\lambda .h}{b}, \qquad (2)$$

Where k is pressure on the front side of teeth [N.m^{-2}],

a_ρ-coefficient of the teeth wear,

p-fictitious specific force on the back side of the teeth [N.m^{-1}],

u_z-feed per tooth [m],

a_λ-intensity of chip friction at the cutting sides [N.m^{-2}].

For determining the cutting power in the experiment was used the following dependence (Gochev 2008)

$$N_{c.} = \frac{(N_{load} - N_{idle})}{100}.\eta, \qquad (3)$$

Where: N_{load}- power of the cutting mechanism in load condition [kW],
- N_{idle}-input power of the cutting mechanism in idle condition [kW],
- η-cutting mechanism coefficient of efficiency.

The calculation of cutting mechanism coefficient of efficiency is accomplished by the equation

$$\eta = (1 - \frac{N_{idle}}{N_{load}}).100. \qquad (4)$$

Figure 5.*General view of the device for power measuring attached to the machine body*

Reporting the input power of the cutting mechanism in load or idle condition was performed by using a device produced by "Unisyst Engineering" Ltd. (Bulgaria) for measuring current, voltage, active, reactive and full power in single or three-phase electric circuit (Figure 5) .

The practice shows that increasing feed speed the band saw blade losses its rigidity and received lumber are with curvilinear surfaces. To avoid the receiving of waste boards the upper feed speed is limited to ≈ 8 $m.min^{-1}$. On the other hand, the logs have irregular geometric shape and the feed speed is variable quantity. Account is taken of its average value

$$U_{av.i} = \frac{L_{\log}}{t_i}, \qquad (5)$$

where L_{log} is length of the log [m],
t_i - time to make a cut on the log [s].

Cutting width is determined by the equation

$$b = s + 2.s', \qquad (6)$$

where s' is tooth part-set size [m].

Due to limitations in the scope of the article the following levels of variation for part-set size and height of cutting are considered:

- black pine: s′=0,2/0,4/0,6 mm; h=120/200/280;
- douglas fir, beech and ash: s′=0,4 mm; h=200.

3. RESULTS AND DISCUSSION

Average values for cutting power ($N_{c.av.}$) for the respective wood species, tooth part-set size, feed speed, cutting height, calculated by equation (3), are presented graphically in Figure 6, 7, 8 and 9.

The graph shows that with increasing the feed speed and the cutting height the cutting power also increases. The dispersion of some results is due to disadvantages of the wood. The machine is not equipped with debarker to prevent from abrasive particles on logs bark. This leads to irregular wear of the teeth and in certain cases tip breaks (Figure 10). As a result, the cutting power increases and some of the experimental tests are repeated.

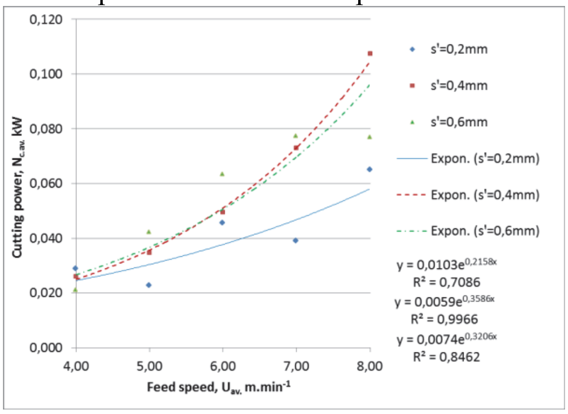

Figure 6. Relationship between the cutting power, feed speed andtooth part-set sizeat cutting height 120 mm

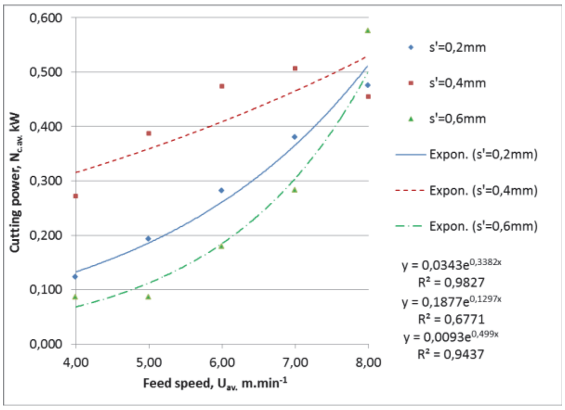

Figure 7. Relationship between the cutting power, feed speed andtooth part-set sizeat cutting height 200 mm

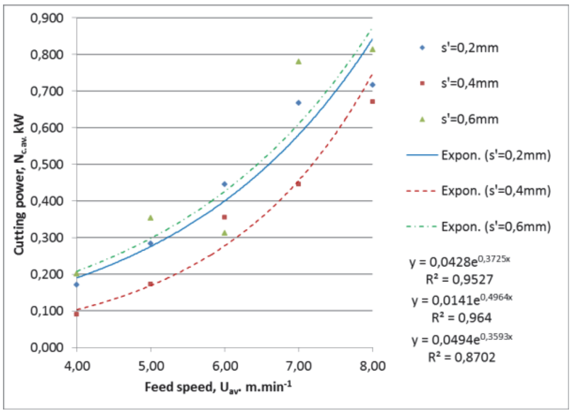

Figure 8. Relationship between the cutting power, feed speed andtooth part-set sizeat cutting height 280 mm

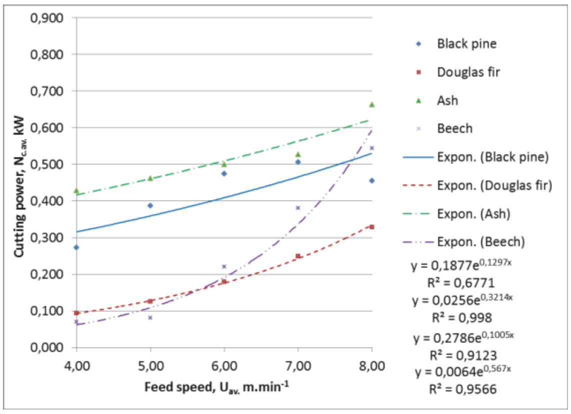

Figure 9. Relationship between the cutting power, feed speed and wood species at tooth part-set size0,4 mm and cutting height 200 mm

Equation (1) shows that with raising the cutting width the power increases. From the graphs of Figure 7 and Figure 8 can been seen that in some of the bands with larger tooth part-set size the cutting power is lower. Probable reason for this is the friction between the band saw blade area and the cutting sides. This leads to further overload of the motor. On the other hand, the smaller values of the tooth part-set size are one of the reasons to obtain curvilinear cuts and deterioration of the quality of machined surfaces (Figure 11) at lower feed speed.

Figure 10. Break off the tips of some teeth due to the abrasives particles on the bark of logs

Wood species also has a significant influence on the cutting power. On Figure 9 can be seen that for ash cutting the values are the highest and for douglas fir the lowest. This is related to the physico-mechanical properties of the wood and particularly its density (ash ρ=777 kg.m^{-3}, dougles fir ρ=545 kg.m^{-3}). When cutting black pine high scores are also received. This can be explained by the large amount of resin and knots. It is noteworthy that the results for beech cutting power are lower. The wood of beech is more homogeneous, moreover, a lot of the cutted logs were affected by fungicides (Figure 12).

***Figure 11**. Curvilinear cut*

***Figure 12.** Deficiencies in the beech wood*

4. CONCLUSION

Based on the studies the following conclusions and recommendations can be made:

1. The right choice for tooth part-set size has considerable influence on wood cutting with band saw blade. The smaller values lead to increasing the frictional force which requires additional power to overcome and also increase the electricity consumption;
2. Feed speed is an important indicator when determining the performance of woodworking machines. It is found that the speed limit where the band loses its rigidity and begins to curve is higher in teeth with larger tooth part-set size;
3. Of particular importance is the right choice of linear and angular parameters of the saw blade and its preparation for work;
4. It is desirable the machines to be equipped with debarker which trimmed the bark before the band saw blade and protects the teeth from abrasive particles.This increases the time for efficient operation of the cutting tool.

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RESISTANCE OF SURFACES TREATED WITH 2K POLYURETHANE AND 2K ACRYL - IZOCYANATE COATINGS TO DRY HEAT

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ABSTRACT

This paper studies the resistance of treated surfaces to the action of dry heat, by observing the changes of the surfaces for a predefined temperature. The surfaces of solid wood samples were treated with two types of coatings: 2K polyurethane and 2K acryl-izocyanate coating. The aim of this study was to determine which of the coatings applied will give a better resistance to dry heat for given temperatures. The test results indicate that the dry heat causes damage with different intensity to the treated surfaces. The surfaces treated with 2K acryl-izocyanate coating show higher resistance than the surfaces treated with 2K polyurethane coating, i.e. the latter areless resistant to the action of dry heat. By applying modified polyurethane coatings, better resistance of surfaces to dry heat is achieved.

Key words: treated surface, coatings, 2K polyurethane, 2K acryl-izocyanate

1. INTRODUCTION

Wood as base with its anatomic structure considerably affects the quality of the surface treated. Taking into consideration the huge number of properties of wood, there is a variety of options in the already defined conditions of surface treatment, starting with choice of suitable wood to economical use of that wood.

Wood preparation, also called pre-treatment of the surfaces, together with application of good quality materials and procedures for surface treatment, are the main factors for achieving surface treatment with appropriate, i.e. predefined quality.

Abrasion products used in wood surfaces treatment are also significant in surface treatment of wood. Different granulations of emery papers allow achieving different levels of smoothness, which is very important for surface treatment. Regarding that, in the preparation stage for surface treatment, the purpose of treatment with emery paper isto increase the surface quality to level suitable for further surface treatment with liquid materials (paints and varnishes)

Varnishes make surface treatment of the wood and their main purpose is protection of the surface of possible damage. Beside protective role, varnishes have other functions such as aesthetic treatment of the surfaces, a requirement that they are also expected to meet.

Their protective function is accomplished by coating the surface as a film, separating it from the environmental factors, moisture, direct contact with liquids and other materials and objects during usage. To fulfill its protective function, the film must be resistant to those factors, so that its protective function would last. Furthermore, those materials must be of such consistency so that they can be easily applied, dried and treated. The aesthetic side is accomplished through transparency, color and different effects of the shine. The transparent layers (transparent to light), allow the surface and the aesthetic value of the wood to be seen, i.e. its texture and color. Pigmented layers can also create different aesthetic effects. The technology of the surface treatment uses various types of coatings in its practice, with different chemical and physical characteristics. In the research for application of the system for protection with coatings, 2K polyurethane and 2K acryl - izocyanate coatings were used.

Research was made to test the heat resistance of these coatings depending on the protective system. The research refers to exploitation of wooden elements in interior conditions.

2. MATERIALS AND METHODS

2.1 Selection of material for base

Sawn spruce wood (*Picea abies* Karst.).was taken as a research surface.Microscopically observed, spruce wood belongs to the group of coniferous wood type. The color of the wood varies from yellowish white to brownish grey and glossy. The white parts are with less shine than the ripe ones. The heartwood does not differ much from the white parts of the wood. Spruce wood has distinguishing growth rings.

Microscopically observed, spruce wood has the following properties: density in absolutely dry state 430 kg/m^3, in slightly dried state 470 kg/m^3 and in raw state 800 kg/m^3. Collecting Shrinkage of spruce wood is: in longitudinal direction 0,30%, in radial 3,60%, in tangential 7,80%, Shoshkic, B., Govedar, Z., Todorovic, H., Petrovic, D., (2007). Total volume shrinkage amounts 12,0% and specific volume shrinkage amounts 0,40%, Urgenovic, A., (1950), Georgievski, Z, (2003), Jevitic, P, (2005).

Spruce wood is soft (270 kg/sm^2), hard under pressure (430 kg/sm^2), weak to bending (660 kg/sm^2). Spruce wood is well and easily treated, well sawn, flattened, emery paper treated and polished and can be widely used. It is well treated with wood turning of lathe, staining, varnishing and it dries easily. The above mentioned implies that spruce wood belongs among the most appreciated types of wood. Namely, the white color of the wood, small-size knots, proper anatomical structure, evenly wide growth rings, small mass, good elasticity and easy treatment, make this wood to be widely used.

Spruce wood has the following chemical composition: lignin 19-29%, carbon-hydrates 67,90-75,70%, which are 41,0-57.80% cellulose, 8,09-13,30% pentosan and 1,10-1,40% acetyl group. The acidity of the water extract is 4,0-5,3 pH, Jevtic, P., (2005).

Sawn wood was dried and conditioned. Average moisture of the spruce was 7,76%. Firstly, sawn wood was evened out so as to get base surface. After that, the thickness of the wood was formed of 15mm.

The dimensions of spruce samples were 200x 100 x 15 mm.

2.2 Preparation of surfaces with emery paper treatment

The emery paper treatment was executed on a wide-band grinder with N^{0}80 emery paper. The following procedure was partial grinding, for each system of preparation of the surface with grinding (system I and II), which were treated in the following way:

- I system: double grinding – numeration N^{0}120 + N^{0}150.
- II system: triple grinding – numeration N^{0}120 + N^{0}150 + N^{0}200.

Technical characteristics of the wide-band grinder:

- manufacturer and machine type: CASOLIN, Italy
- type of pressure element: pressure beam
- grinding speed: 17m/s
- auxiliary movement speed: 20 m /min.

2.3 Preparation and application of 2K polyurethane coating

For treatment of the sample surfaces, a basic and finishing (shining) 2K polyurethane coating was used.

Both base and finishing coatings were prepared by mixing the components "A" and "B" (base and fixer), right before application, with mixing ratio 2:1. Coating was applied by spraying. All the samples were sprayed with same quantity of coating, which was 180g/m^2, with deviations of $\pm$ 5%. The conditions of spraying the coating are given in Table 1.

After drying the base coatings, before applying the finishing coating, an inter-phase N^0 240 emery paper treatment was performed.

Table 1. *Conditions for applying 2K polyurethane coating*

Parameters	Value
Way of spraying	Air spraying
Spraying pressure	3,0 bar
Nozzle diameter	1,2 mm
Distance of the nozzle from the material treated	250 mm
Temperature of the coating	20 ^oC
Coating viscosity	20 s (F4/20 ^oC)
Temperature of the ambient air	21 ^oC
Relative humidity of the ambient air	60%
Quantity of the material applied	180 $g/m^2 \pm 5\%$

2.4 Preparation and application of the 2K acryl-izocyanate coating

Treatment of the surface of the samples was made with base coating with polyurethane and finishing (shining) coating with 2K acryl - izocyanate coating.

The base and finishing coatings were prepared by mixing the components “A” and “B”, right before applying them, with mixing ratio 2:1 and 5:1.

Applying of the coating was performed with air spraying. Each sample had the same quantity of coating, amounting 150 g/m^2, with deviation of $\pm$ 5%.The coating application conditions are given in Table 2.

After drying of the base coating, before applying the finishing coating, manual inter-phase N^0 240 emery paper treatment was performed.

Table 2. *Applying conditions for 2K acryl-izocyanate coating*

Parameter	Value
Way of spraying	Air spraying
Spraying pressure	3,0 bar
Nozzle diameter	1,2 mm
Distance of the nozzle from the material treated	250 mm
Temperature of the coating	20 ^oC
Coating viscosity	19s (F4/20 ^oC)
Temperature of the ambient air	21 ^oC
Relative humidity of the ambient air	60%
Quantity of the material applied	150 $g/m^2 \pm 5\%$

2.5 Determining resistance to dry heat

The procedure for testing the resistance of varnished surfaces to dry heat is defined by the EN 12722 standard. This standard anticipates putting heated body onto the surface and monitoring of the changes for the predefined temperature.

The changes were classified in five groups and graded from 5 to 1 (Table 3).

Table 3. *Classification of resistance of the coating to dry heat*

Grade	Change of the surface
5	There are no visible changes (no visible damage)
4	Slight change in the shine, visible only when the source of light is mirrored on the surface treated with dry heat or in its vicinity
3	Slightly visible stains, visible from a few watching directions
2	Clearly visible stains, visible from all watching directions, change in the structure of the surface
1	Clearly visible stains, significant change in the structure of the surface or the protective coating is partially or fully removed

3. RESULTS AND DISCUSSION

The results of testing the resistance of the film of coating to dry heat, for temperatures: 100°C, 140°C, 180°C, are shown in the tables 4, 5 and 6 and graphically in Figures 1, 2 and 3.

Table 4. *Resistance of the film of coating to dry heat (at 180°C)*

Ord. No.	Grinding system $N^0120 + N^0150$	Grade of change (180°C)	Ord. No.	Grinding system $N^0120 + N^0150 + N^0200$	Grade of change (180°C)
Basic polyurethane coating 2x + Finishing polyurethane coating 1x					
1.	System I	3	5.	System II	3
2.	System I	3	6.	System II	3
Basic polyurethane coating 2x + Finishing acryl-izocyanate coating 1x					
3.	System I	4	7.	System II	4
4.	System I	4	8.	System II	4

Table 5. *Resistance of the film of coating to dry heat (at 140°C)*

Ord. No.	Grinding system $N^0120 + N^0150$	Grade of change (140°C)	Ord. No.	Grinding system $N^0120 + N^0150 + N^0200$	Grade of change (140°C)
Basic polyurethane coating 2x + Finishing polyurethane coating 1x					
1.	System I	4	5.	System II	4
2.	System I	4	6.	System II	4
Basic polyurethane coating 2x + Finishing acryl-izocyanate coating 1x					
3.	System I	5	7.	System II	5
4.	System I	5	8.	System II	5

Analyzing the results of resistance of the film of coating to dry heat shown in tables 3.1 - 3.3, we can see that the applied system of preparing the surface does not affect the resistance to dry heat

Concerning the type of the finishing coating applied, there is a difference in the results obtained from testing the resistance to dry heat. Namely, the surfaces of the samples treated with finishing acryl-izocyanate coating showed better resistance of the film of coating to dry heat. Samples treated with finishing 2K polyurethane coating showed smaller resistance of the film of coating to dry heat, for all three testing temperatures. At temperature of 180^{o}C, visible stains occurred on the samples' surfaces, and at temperatures of 140^{o}C and 100^{o}C, a slight change of the shine occurred.

Table 6. *Resistance of the film of coating to dry heat (at 100^{o}C)*

Ord. No.	**Grinding system N^{0}120 + N^{0}150**	**Grade of change (100^{o}C)**	**Ord. No.**	**Grinding system N^{0}120 + N^{0}150 + N^{0}200**	**Grade of change (100^{o}C)**
Basic polyurethane coating 2x + Finishing polyurethane coating 1x					
1.	System I	4	5.	System II	4
2.	System I	4	6.	System II	4
Basic polyurethane coating 2x + Finishing acryl-izocyanate coating 1x					
3.	System I	5	7.	System II	5
4.	System I	5	8.	System II	5

The biggest changes in the surfaces of the samples occurred treatment with dry heat at temperature of 180^{o}C.

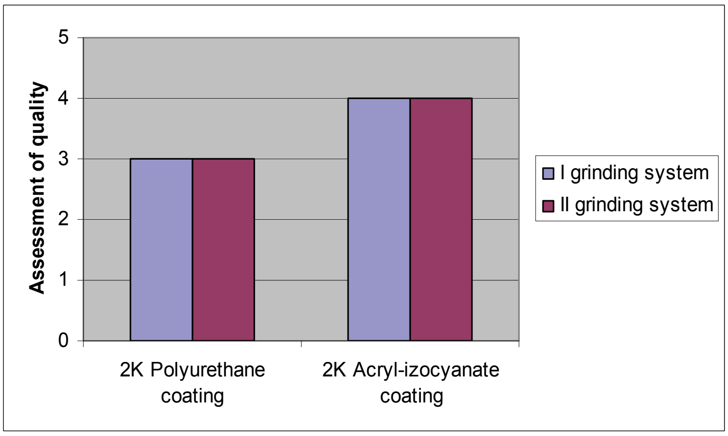

Figure 1. *Resistance of varnished surfaces of samples treated with dry heat (t = 180^{0}C)*

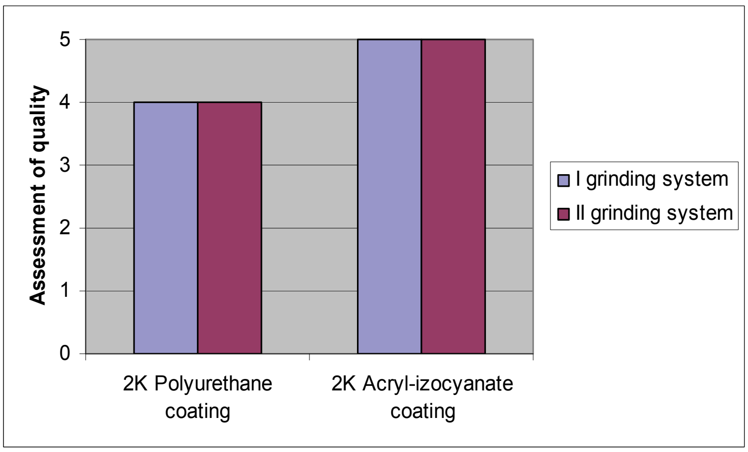

Figure 2. *Resistance of varnished surfaces of samples treated with dry heat (t = 140^{0}C)*

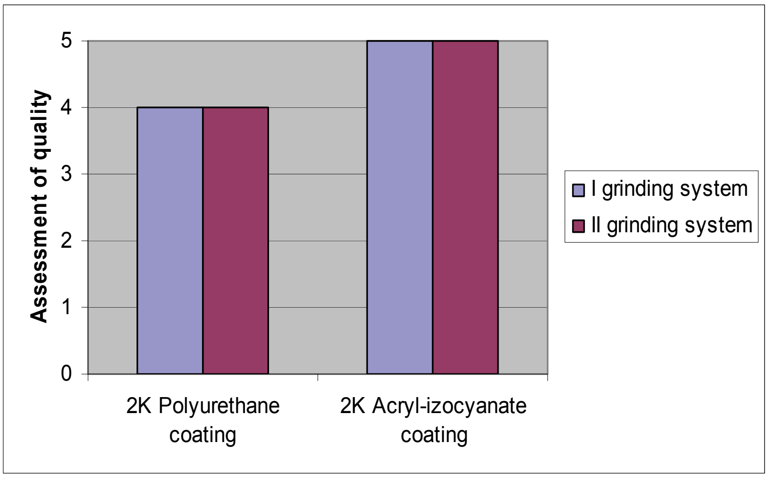

Figure 3. *Resistance of varnished surfaces of samples treated with dry heat ($t = 100^0C$)*

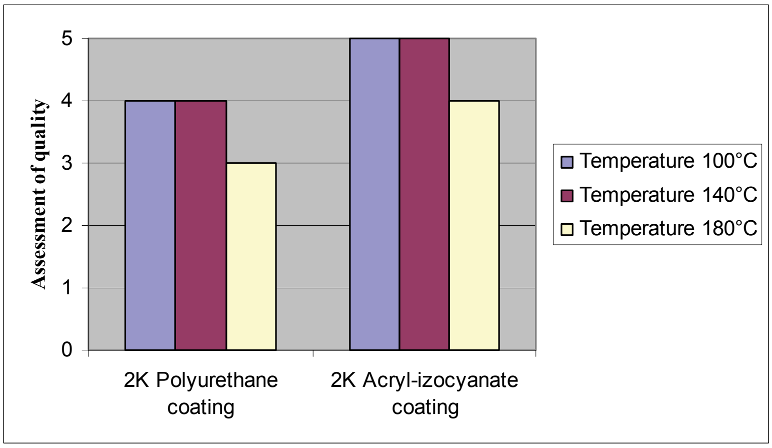

Figure 4. *Resistance of varnished surfaces of samples treated with dry heat*

With this research it was impossible to ascertain the effect of the system of preparation of the surface with emery paper treatment to dry heat, because the results were equal.

Similar results were obtained by the author of the research in the paper Jevtic, P., (2005) where it was established that preparation of the surfaces with grinding has little effect on the resistance of the film of coating to dry heat.

The resistance of the film of coating to dry heat is relatively good with both types of finishing coatings and for both systems of preparing the surface with grinding.

4. CONCLUSION

Coating protection systems affect the quality of the surface treatment of the wood. 2K acryl-izocyanate coating reached higher resistance to heat (dry heat at 100^o C, 140^o C and 180^o C).

Research results indicate that 2K acryl-izocyanate coating systems are of high quality, which justifies our expectations that modified polyurethane, regarding the properties of their treated surfaces, are better than the most commonly and conventionally used polyurethane coatings which are used for protection of the wood surface.

Modified coating systems (2K acryl-izocyanate), offer better quality protection of the final spruce wood products in the interior.

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RESEARCHING THE DIMENSIONAL STABILITY OF THERMALLY MODIFIED WOOD

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ABSTRACT

The swelling properties of thermally modified spruce wood samples and their ASE became the object of the current research. The thermally treatments were at temperature of 200ºC in air environment and in different plant oils. These samples are obtained by different methods and treated with various protective coatings. Some control test samples were also made. Four different types of coatings were used: alkyd organic coating system, waterborne acrylate system, bee wax product and plant oil product. Finished products were soaked in distilled water. The results show that thermally modified wood improves its dimensional stability. It is even more stable when it is finished with protective coatings afterwards. The best results are present after treating the spruce wood in soya oil environment and finishing the samples with Valtti color.

Keywords: spruce thermally modified wood; dimensional stability; finishing; coats

1. INTRODUCTION

Thermal treatment is good alternative to chemical modification for wood and guaranties good dimensional stability. [1].This treatment changes the structure of cell walls in wood; the result of this is lower absorption ability, lower density and better resistance on fungi attacks. It is useful on conifer species (softwood) and on hardwood species as well. The results of thermal treatment (190-220°C) are destruction of hemicelluloses and separation of some extractives from wood.

The thermally modified wood has a soft brown colour, depend of the temperature of receiving with well-defined texture. Thermally modified wood has two standards about treatment classes: Thermo-S and Thermo-D. Thermo-S is wood received after heated to 190ºC. Thermo-D is wood received after heated to 212ºC (Termowood handbook 2003-www.thermowood.fi). The average tangential swelling and shrinkage due to moisture for Thermo-S class treated wood is 6-8%. The average tangential swelling and shrinkage due to moisture for Thermo-D class treated wood is 5-6%. The decreased equilibrium moisture content of the wood improves its stability, which in turn reduces the cracking of the wood. Thermally modified wood has possibility to be received in different environment. Heat treatments usually take place in an inert gas atmosphere at the temperature between 180-260°C [4]. The boiling point of many natural oil and resins are higher than the temperature required for the heat treatment of wood. This open us the option of the thermal treatment of wood in a hot oil bath (Rapp and Sailer 2001).

Uncoated thermally modified wood has good dimension stability but they need of coating for better outdoor exploitation. Oil-based substances work as with normal wood. When one works with water-based substances, it has to be taken into account that Termowood has lower water absorption than normal wood (Termowood handbook 2003).

2. MATERIALS AND METHODS

This investigation is comparable for four different series spruce wood (Picea abies L.) and control 10 samples (5 radial and 5 tangential) for each series with measurement: 21x72x150 mm (last one is on fiber length). These series are: thermally modified wood in air environment (first index D); thermally modified wood in corn oil environment (first index B); thermally modified wood in soya oil environment (first index O); and Thermo-S (first index T). The control samples are obtained from same wood in drying kiln with temperature 103°C for 48 hours. They are marked with first index K and second index about applied coating, also it has control samples without coatings, marked with TKP (Termo-S spruce wood) and KP (natural spruce wood). The heat treatments for series are organized in the same temperature regime (Figure.1).

The obtained thermally treated wood samples, control samples and supplied Thermo-S are coated with four different protective systems: waterborne acrylate self sealer Panneli assa (second index A) with average consumption 200 g/m²; waterborne wax Valtti Ulkovaha (second index W) with average consumption 100 g/m²; alkyd lacquer modified with linseed oil Valtti color (second index V) with average consumption 150 g/m²; linseed oil product Valtti wood oil (second index O) with average consumption 120 g/m². All of these are produced of Tikkurila Oy- Finland,

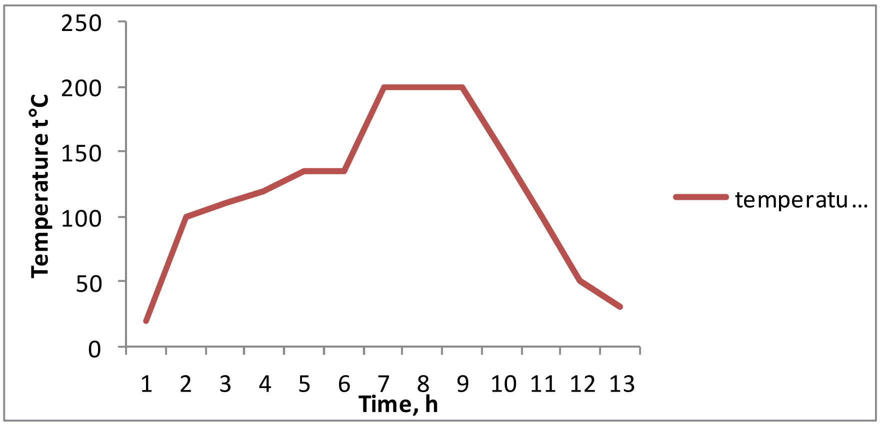

Figure 1. *Thermally treatment graphic*

The obtained samples are soaking in tank with water. They are controlled periodically. The samples measure in width and in thickness on three places; in the middle and 20 mm from the ends. The weight is also measure periodically. The first three measurement are done an hour between and after that on 72 hours till 384-th hour. The results for swelling and ASE are put on table. The kinetic of sorption is shown in diagrams. The each series is compare with control samples, which are put in same condition**.**

The water absorption is determinate for every measurement with next (6) formulas:

$$M_w = \frac{M_T - M_H}{M_H}.100,\% \qquad (6)$$

where:
M_w is mass changing in result of water absorption; M_T is current mass; M_H is initial mass;

The swelling of the samples is determinate for every measurement with next (7) formulas:

$$S = \frac{a_t - a_n}{a_n}.100,\% \qquad (7)$$

where: S is swelling of the samples; a_t is current measure of samples; a_H is initial measure of the samples;

The anti swelling effect (ASE) is determinate for every measurement with next (8) formulas:

$$ASE = \frac{S_{nw} - S_{mw}}{S_{nw}}100,\% \qquad (8)$$

where: S_{nw} is swelling of untreated wood; S_{mw} is swelling of treated wood (thermo wood;)

3. RESULTS

The average values are present in table №1. The kinetic of water sorption for different series are present in four graphics, in function of applied coatings (Figure 2; 3; 4 and 5). The results in Table 1 show that density of spruce decrease after heat treatment in this regime in dry air environment with 9.19 %. (from 457 kg/m³ to 415 kg/m³). It was proved that this process is result of hemicellulose and extractive corporeal hydrolysis in wood. It leads of more water sorption from 71.11 % to 82.41 %, as result of more volume gaps between cells. The other sight of process is changes in microstructure of cell walls, which reduce swelling in two directions.

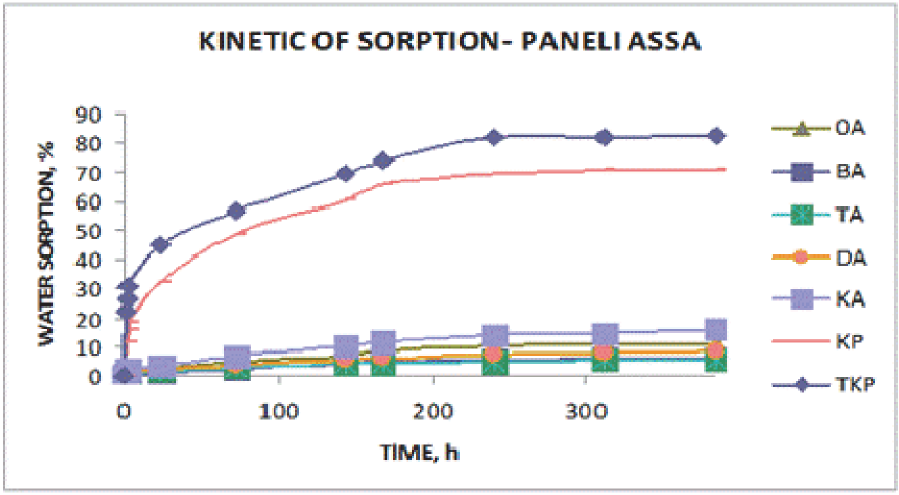

Figure 2. *Kinetic of water sorption of spruce thermally modified wood, coated with Panneli assa*

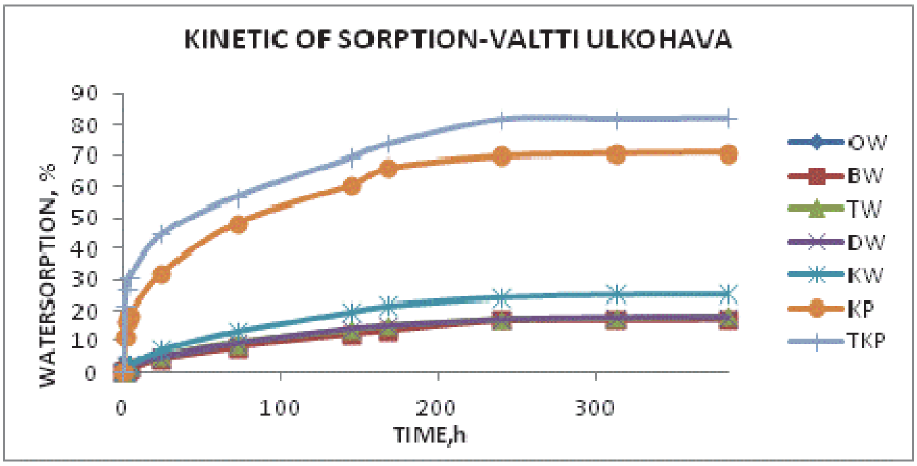

Figure 3. *Kinetic of water sorption of spruce thermally modified wood,coated with Valtti ulkohava*

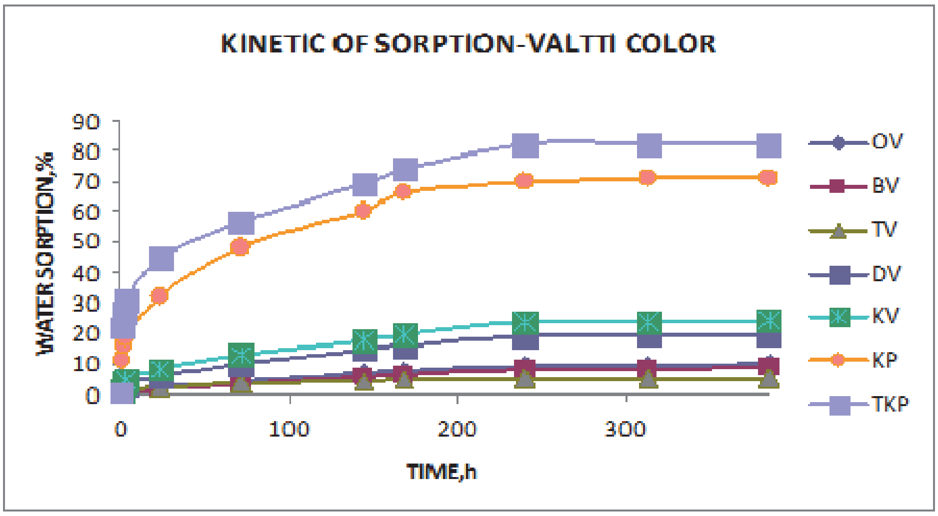

Figure 4. *Kinetic of water sorption of spruce thermally modified wood, coated with Valtti color*

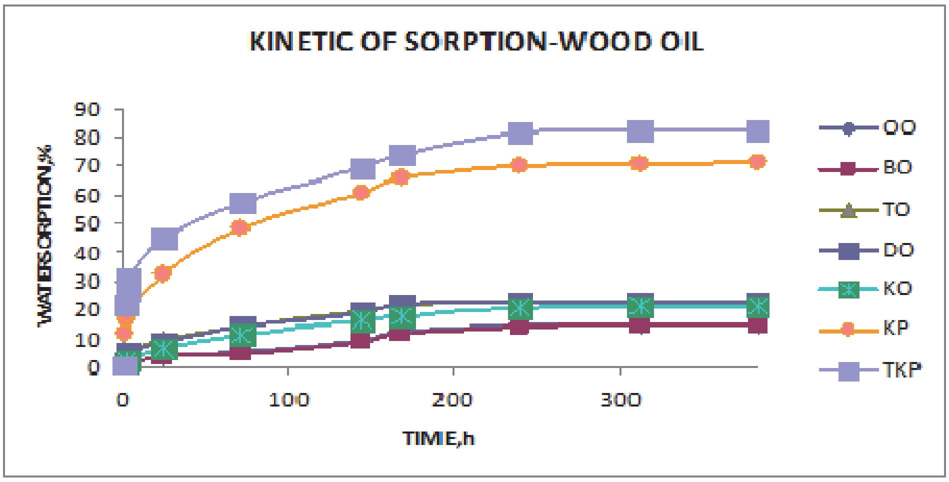

Figure 5. *Kinetic of water sorption of spruce thermally modified wood,coated with Wood oil*

The swelling reduce in tangential direction from 8.14 % to 3.29 %, and in radial direction from 6.59 % to 3.11 %. Thermally treated wood (TKP) have a high ASE: 59.58 % in tangential direction and 51.33 % in radial.

The analysis of results from Table 1 are that the wood density increase in result of heat treatment in oil environment to 200°C (from 457 kg/m³ to 656 kg/m³ in soya oil environment and to 706 kg/m³ in corn oil). It is density increase with 43.54 % about soya oil and 48.63 % about corn oil. In our practice obviously formed coatings for better and longer exploitation, this increased ASE.

The best result in Table 1 is for samples heat treated in soya oil environment and coated with Valtti color (OV): $ASE^{r} = 74.8\ \%$. The influence of coating systems are proving by series: *KA; KW; KV* and *KO*. The most effective coating from table 1 is waterborne acrylate lacquer (Panneli assa)-***KA***: $ASE^{T} = 25.80\ \%$ and $ASE^{r} = 30.80\ \%$.

***Table 1**. Swelling and anti -swelling effect (ASE) of thermally modified spruce wood*

Index	$D_{tmwo}, kg/m^3$	$\Delta M,\%$	$Q_L, g/m^2$	$W_{ab},\%$	$S^t,\%$	$ASE^T,\%$	$S^r,\%$	$ASE^r,\%$
OO	656	43,54	100	14,91	3,29	59,58	2,28	64,31
OA	656	43,54	180	11,14	4,48	44,96	3,11	51,33
OW	656	43,54	85	17,48	5,41	33,54	3,41	48,25
OV	656	43,54	145	10,04	7,77	4,55	1,61	74,8
BO	706	48,63	100	14,78	5,10	37,34	3,2	51,44
BA	706	48,63	180	5,91	4,43	45,57	2,97	53,52
BW	706	48,63	85	17,15	6,25	23,22	3,2	51,44
BV	706	48,63	145	8,97	3,12	61,67	2,82	55,87
TO	436	-	120	22,54	3,20	60,69	2,82	55,87
TA	436	-	180	5,65	3,15	61,3	2,5	60,88
TW	436	-	100	18,11	3,20	60,69	2,8	56,18
TV	436	-	150	5,60	3,12	61,67	1,75	72,61
DO	415	-9,19	120	22,40	5,87	27,89	4,57	30,65
DA	415	-9,19	180	8,35	3,98	51,1	1,91	70,11
DW	415	-9,19	100	16,03	5,41	33,54	3,21	51,29
DV	415	-9,19	150	18,03	3,29	59,58	3,11	51,33
KP	457	-	-	71,11	8,14	-	6,59	-
TKP	436	-	-	82,41	3,29	59,58	3,11	51,33
KA	457	-	180	19,94	6,04	25,80	4,56	30,8
KW	457	-	100	25,39	6,70	17,69	4,97	24,58
KV	457	-	150	24,21	6,60	18,92	4,61	27,01
KO	457	-	120	43,52	6,64	18,43	4,99	24.28

Legend: D_{tmwo} – density of absolutely dry wood; ΔM - mass increase after thermally treatment ; Q_L - mass of coating; W_{ab} - mass of absorbed water; S^t - swelling in tangential direction; S^r - swelling in radial direction; ASE^T - anti-swelling effect in tangential direction ; ASE^r - anti-swelling effect in radial direction .

4. CONCLUSION

Thermally treatment is a process, which increases wood dimension stability. The better wood dimension stability is a function of some factors like an environment, temperature, duration of thermally treatment and type and application of protective decorative coating. This investigation gives a proof for treatment in oil environment and using coatings formed with alkyd modified with linseed oil (Valtti color) and waterborne selfsealer (Panelli assa). These defense operations are useful for cottages, balconies and wooden part for outdoor exploitation. Thermally treatment processes gave good dimensional stability and also reduced the differences between radial and tangential samples. The coatings formed on this wood give us a better water protection.

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PERCENTAGE OF WEIGHT INCREASE IN EUROPEAN SPRUCE WOOD (*Picea Abies.*Mill), IMPREGNATED WITH POLYURETHANE AND ACRYLIC COATINGS

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ABSTRACT

Capillary absorption - impregnating the wood with filmogenic materials, represents a possible method for surface modification of the wood. By application of double vacuum process, polymeric filmogenic materials are incorporated into the cellular and intracellular cavities of the wood surface layers. The Weight Percent Gain - WPG is significantly larger than with classically coated wood.

The progress rate of WPG of two dimensions of test pieces in the impregnation process with polyurethane coating is 11.39% and 36.03%, and in impregnation with acrylic coating it is 10.60% and 28.70%. The differences in impregnated wood with polyurethane and acrylic coating are not statistically significant.

Key words: impregnation - capillary absorption, European spruce, polyurethane coatings, acrylic coatings, the Weight Percent Gain

1. INTRODUCTION

Modification of wood is change of the natural features in order to improve the properties and the duration of use. The main objectives are: dimensional stability, improved mechanical properties, resistance to biological degradation. For modification of wood, procedures are used that affect the basic structure elements, which are: cellulose, lignin and hemicelluloses. Modification can occur in three groups of changes (Homan, 2004): lumen filling, filling of cavities in the cell wall and chemical bonding - chemical modification.

Capillary absorption is an impregnation method where vacuum and normal pressure are applied, by which an impregnation material is introduced in wood, but capillary saturation does not necessarily occur. Capillary absorption and impregnation in relevant textbooks are also referred to as: “Resin impregnation", “Impregnation modification", “Hardened wood", “Wood-Polymer Composite", “Wood stabilization".

2. RESEARCH GOAL

The aim of the research is to see the performance of capillary absorption as a method of impregnation and to identify the differences between modification of the surface layer with capillary absorption of two types of filmogenic materials. Given that nowadays many filmogenic materials are available on the market of raw materials, through study of past experiences of researchers from the available literature data, our primary goal is to identify two types of filmogenic materials which will be mutually comparable for the purposes of this research.

With this research we are interested in defining the amount of material that can be capillary absorbed by wood.

3. RESEARCH TO DATE

Occurrences, properties and laws that are specific to the process of impregnation of wood, defined by three distinctive phenomena are: absorption, penetration and fixation (Bahchevandzhiev., K. 2001). To achieve maximum impregnation material absorbed by wood (Videlov., H. 1980), when comparing feasible and theoretically calculated quantity, more parameters have to be met. When soaking wood, maximum amount of absorption is up to 10%, and with combined vacuum and pressure, it is up to 95%, theoretically calculated. The absorbed urethane diisocyanate polymers react with the hydroxyl groups of the wood matter.

The initial researches with isocyanates (Baird, 1969) of veneer sheets treated with phenyl isocyanate and dimethylphonamide, were concerned with improvement of dimensional stability.

The Authors (Clermont and Bender, 1957), with ethyl, n - butyl and t - butyl isocyanates, catalyzed with dimethylphonamide achieved an increment in weight of WPG = 31%.

When Methyl isocyanate polymerized in wood with no catalyst added, (Rowell and Ellis, 1979) they machieved WPG = 35%. Further absorption of resin rapidly reduced the percentage of dimensional stability. This is explained with the excessiveness of resin, which in the networking process destroys the cell wall and water easily comes in contact with the crumbled wood matter.

Acrylic resin of vinyl type, with a catalyst, reacts with the hydroxyl groups in the wood and gives reaction of cyanoethylation. Experiments were made with methyl methacrylate monomer (MMA), (Rosen 1976, Saiu and Meyer 1966, Meyer 1977, 1984) and scientists achieved WPG = 100%, but they confirmed that the excessiveness of resin destroys the cell wall when networking and water smoothly penetrates into the wood. The same was confirmed by (Ellis, 1994, Zhang, 2006, Wei Ding, 2009), but improvement of some mechanical properties was confirmed. Acrylonitrile catalyzed by sodium hydroxide gives good results (Baechler, 1959) WPG = 30% and with ammonium hydroxide as a catalyst, WPG = 26%. The disadvantage of this resin is water solubility in warm water, or to putting it better, the resin is rinsed with the wood.

Impregnating of the wood with difunctional monomer, glycidyl methacrylate (GMA) containing epoxy group (Rozman, Rahim and Mohamad, 2007) in the cavities of the cell wall reacts with the free OH groups of cellulose, reaching WPG = 47% and is considered to be best combination achieved.

4. ORIGIN OF THE MATERIAL AND METHOD OF OPERATION

4.1 Manufacture of wood test pieces

Test pieces were made of spruce wood (Picea abies), material from a local sawmill from Macedonia. Wood without visible flaws was selected, with average growth in radial direction of up to eight annual rings at each 10mm. The test pieces were brought to equilibrium moisture of wood of W = 13 ± 2%, by weight allowable tolerance of ± 1,5%, according to ISO 554:1976.

Two sets of test pieces were treated for each type of filmogenic material - coating with n = 31 up to 34 numbers. From each coating were impregnated: - a group of samples measuring 150x70x20mm, impregnated with polyurethane (IPUL) and a group impregnated with acrylic group (IAKL) and - a group of samples measuring 30x20x20mm, impregnated with polyurethane (IPUD) and a group impregnated with acryl (IAKD).

Determination of the percentage of moisture and the wood volume mass was made in accordance with the ordinary methods prescribed by ISO 3130 and ISO 3131 standards.

4.2 Properties of Coatings

Coatings tested are based on polyurethane and acrylic resins, standard products from the range of a renowned European manufacturer (ICA LP152P and ICA LAC367). Preparation of coatings was performed according to prescribed instructions from the manufacturer, and the coatings were not additionally diluted.

Viscosity was determined in compliance with ISO 2431, percentage of dry residue according to ISO 1515.

4.3 Procedure for Capillary Absorption

Capillary absorption of coatings by wood was performed according to the Double vacuum process (Videlov., H. 1980, Richardson, B. 2003). Wooden test pieces were fully immersed into the coating solution used as an impregnator. The last treatment with vacuum, after removing the autoclave impregnating solution, was performed in order to prevent formation of a film on the wood surface.

The ratio between pressure and duration of action is shown in Figure 1.

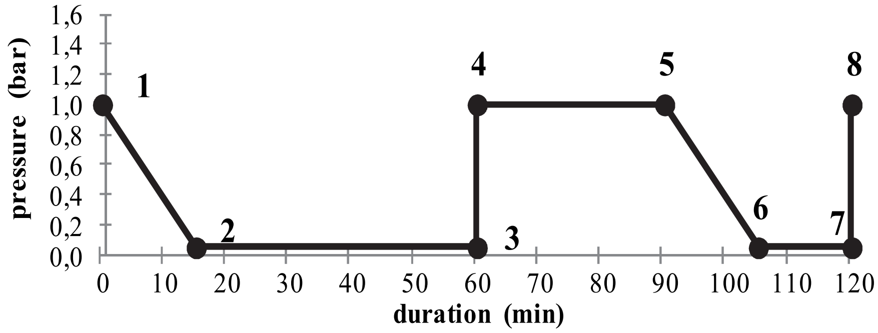

***Figure 1**. Mode of treating samples*

After treating he test pieces, polymerization of the filmogenic material occurs. The process of polymerization is monitored until reaching constant weight, in conditions prescribed by ISO 554:1976.

4.4 Weight Percent Gain

The increase in weight or "Weight Percent Gain "- WPG, (Hill 2006), is percentage increase of the weight of the sample after treatment, compared to its initial weight.

$$WPG\ (\%) = \frac{Mm - Mu}{Mu}$$

M_m- mass of the treated sample (g); M_u - mass of the sample before treatment (g)

4.5 Statistical Data Processing

The obtained values were statistically processed according to the usual methods of variation statistics. The check of the differences between two mean values (significance) for statistical totals of over 30 measurements, was determined by:

$$T = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

The level of significance of the test is $\alpha = 0.01$, i.e. the degree of certainty of 99%, with critical values outside the threshold $\pm$ 2.58.

5. RESULTS AND DISCUSSION

5.1 Properties of Coatings

The average viscosity of polyurethane coating is v_{pu} =15" F4/20°C, of acrylic coating is v_{ak} = 27" F4/20 ° C. During the procedure viscosity remains unchanged. The mean value of dry residue in polyurethane coating is C.O. $_{.pu}$ = 49.3 (%), and in acrylic coating C.O. $_{ak}$ = 54 (%). Although acrylic coating has slightly higher quantity of dry residue, the difference of 4.7% is statistically insignificant.

5.2 Properties of wood

The average value of moisture content in wood was W = 11.57 ± 0.21%.The average value of volume mass of spruce wood in working percentage of moisture was ρ_{12} = 0,44 ± 0.03g/cm^3.

The volume mass was in the range (ρ = 0,33 to 0,68 g/cm^3) of the reference data, (Pejoski, b., 1966), which is an interval of volume mass in spruce wood from Macedonian region.

5.3 Increasing the Mass

Comparison of groups is aimed at establishing whether there is a significant difference between the increase percentage in mass in wood impregnated with polyurethane and in wood impregnated with acrylic coating.

The results of the measurements are shown in Table 1 and are graphically presented in Figure 2.

The mean value of increase in weight of wood, Table 1, column 3, impregnated with polyurethane filmogenic material WPG_{ipul}, is higher than the mean value of wood impregnated with acrylic filmogenic material WPG_{iakl}.

The absolute difference between the mean values of wood weight increase is 0.8%, or in percentage, wood impregnated with polyurethane filmogenic material has by 7.5% higher mean value than wood impregnated with acrylic filmogenic material. The factor of significance is low T = 0:19, and the difference is not statistically significant.

Table 1. *Values of increase in weight with impregnated test pieces.*

No.	Property tested	Test pieces (150 x 70 x 20mm)		Test pieces (20 x 20 x 30mm)	
		Polyurethane – IPUL	Acryl – IAKL	Polyurethane – IPUD	Acryl - IAKD
1	2	3	4	5	6
2	Increase in weight – WPG (%)	11.39 ± 6.71	10.60 ± 7.79	36.03 ± 21.19	28.70 ± 15.55

The mean value of increase in weight of wood, shown in Table 1 column 5, impregnated with polyurethane filmogenic material, is also higher than the mean value of wood impregnated with acrylic filmogenic material.

The absolute difference between the mean values for these groups was 7.3%, or in percentage, wood impregnated with polyurethane has by 25,4% higher mean value than wood impregnated with acrylic coating. Despite the difference, the significance factor T = 1:55 shows that it is statistically insignificant.

The polyurethane coating with properties v_{pu} = 15" F4/20°C and C.O.$_{pu}$ = 49%, when impregnating the wood, depending on the samples dimensions, gives percentage increase in mass WPG_{ipul} = 11.39% and WPG_{ipud} = 36.03 %.

The acrylic coating has v_{ak} = 27" F4/20°C and S.O. $_{ak}$ = 54%, and thus gives the percentage increase in weight of the wood WPG_{iakl} = 10.60% WPG_{iakd}=28.70%.

The coating with lower viscosity, in this case polyurethane, gives higher percentage of increase in weight. Polyurethane coating, due to the lower viscosity, penetrates deeper inside the wood.

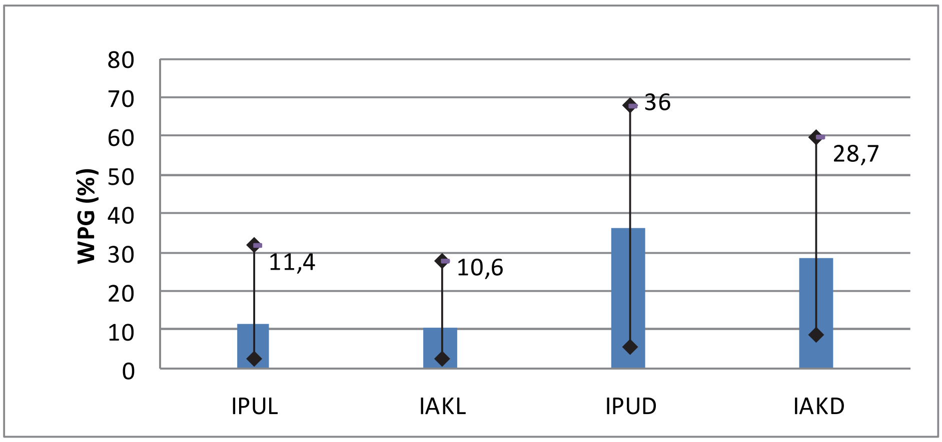

Figure 2. *Graphical representation of increase in weight - WPG, in impregnated test pieces*
IPUL - wood impregnated with polyurethane coating tested on water permeability, IPUD - wood impregnated with polyurethane coating tested on dimensional stability, IAKL - wood impregnated with polyurethane coating tested on water permeability, IAKD - wood impregnated with polyurethane coating tested on dimensional stability

After evaporation of the solvents, wood remains with higher percentage of dry matters, and accordingly a higher percentage of weight increase. The values of viscosity and dry residue are within the recommended values (VidelovH., 1980), i.e. during impregnation process viscosity is supposed to be lower than v = 40" F4/20°C. Low viscosity is due to the higher proportion of solvents in the coating composition, hence the smaller percentage of dry residue. Dry residue of the coatings, according to the same author, is within the recommended values i.e. less than 55%.

According to data, (Richardson., B, 2003), the most important factor which affects penetration of the coating into wood, and accordingly wood weight, is the coating's viscosity. But with addition of solvents, beside reducing the viscosity of the coating, which leads to change of molecular weight of the dissolved material, we simultaneously alter the percentage of dry matters (Jaic., M. 2001). The composition of the coating which contains a lower percentage of dry matters - non-volatile substances, contains a higher percentage of solvents – volatile substances - Grejstoun, Bulijan (Graystone. J, Bulian.F,2009).

Penetration of the materials in wood depends on other physical and chemical properties of the impregnating material (Videlov.H., 1980), as well as polarity and surface voltage of liquids. Impregnating solutions with low viscosity, high polarity and surface voltage, penetrate evenly and deeper into the wood. Highly viscous materials are characterized by high coefficient of internal friction and large hardly movable molecule, their penetration in wood is slight and they are mostly deposited in the macro capillaries of the basic structure elements.

Polarity is a phenomenon that occurs in covalent links in molecules due to the difference in electronegativity of the atoms. The filmogenic materials - coatings used for capillary absorption - are composed of polymers. Molecules in polymers are linked to each other by covalent bond, which can be polar and non-polar. Polyurethane and acrylic coating are highly polar (Smith.J., 2009). Wood is polar, natural polymer, which chemically well agrees with polarized covalent molecules and builds covalent relationships with them. Poorly polar molecules do not link with wooden material with covalent bond, but with simple hydrogen bonds, and are attracted by Van-der-waals interactions (Jaic., M., 2006).

According to the above, we can conclude that wood with its polarity has chemical affinity towards polarized molecules of polyurethane and acrylic coating, which leads to good penetration of filmogenic materials and increase in wood weight, and also has all the prerequisites for building a stable covalent bond.

Previous researches (Liu and McMillin 1965) give the minimum value of the percentage of the weight increase WPG = 10%, treated with epoxy resin. The highest reached percentage of increase in weight of wood WPG = 100%, was when treated with methyl methacrylate monomer (Rosen 1976, Saiu and Meyer 1966, Meyer 1977,1984). However, in referential books there is no data on the impregnation regime, the strength and duration of pressure, viscosity, resin density and wood type.

According to referential data, when impregnating wood with polyurethane resins, the lowest achieved weight increase percentage is WPG = 31% (Clermont and Bender 1957), and the highest is WPG = 35% (Rowell and Ellis 1979). When impregnating wood with acrylic resins, the percentage of wood weight increase ranges from WPG = 26 to 30% (Baechler, 1959), but there is no available data on the type of wood, the impregnation procedure and properties of materials. The authors (Rozman, Rahim and Mohamad, 2007) impregnated rubber wood (Hevea brasiliensis), with glycidyl methacrylate (GMA) - monomer, in conditions of 0.03bar vacuum and duration of 25min., achieving an increase in the mass of wood of WPG = 47%, on pieces with dimensions 30 x 20 x 20mm.

The properties of monomer and wood are not displayed. In our study, with wood of identical dimensions and roughly the same vacuum and duration, with acrylic and polyurethane filmogenic material, we achieved wood weight increase percentage from WPG = 28 to 36%.

In the end let us mention that when there is an increase in wood weight exceeding WPG = 35%, in wood treated with polyurethane, when resin is networking, a macromolecule is created that destroys the cell wall and leads to negative changes in wood material (Rowell and Ellis 1979).

6. CONCLUSIONS

Based on the research conducted, the following major conclusions can be made.

1. Capillary absorption is a method of impregnation, when vacuum and normal pressure are combined and thus impregnating material is introduced in the wood, where capillary saturation does not necessarily occur.
2. The percentage of increase in weight in wood impregnated with polyurethane and wood impregnated with acrylic coating is equal, i.e. the influence of these filmogenic materials is equal. With polyurethane coating the values achieved were as follows: WPG = 11,39% with samples measuring 150x70x20mm and WPG = 36% with samples measuring 30x20x20mm, whereas with acrylic coating the values were as follows: WPG = 10,60%., with samples measuring 150x70x20mm and WPG = 28,70% with samples measuring 30x20x20mm.
3. The percentage wood weight increase - WPG achieved by the procedure of impregnation with capillary absorption, ranges within the above values from relevant literature, regardless the procedure and mode of impregnation, type and properties of wood and materials used.

We can conclude that increases in weight obtained in this research are within the practically confirmed and relevant literature values, i.e. with the method of impregnation with capillary absorption we modified the properties of wood.

The results of wood processing, impregnation with capillary absorption, suggest a possible practical application of this method as a surface treatment technology, specifically modifying the surface layer of wood. This method can also be applied for impregnation with special purposes.

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INVESTIGATION OF THE NATURAL FREQUENCIES AND THE MODE SHAPES OF THE CIRCULAR SAW USING FINITE ELEMENTS METHOD. PART II: NUMERICAL INVESTIGATIONS

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ABSTRACT

This paper shows the methodic and results of the simulative investigations of the circular saw. The natural frequencies and mode shapes of the circular saw are obtained as results from the investigations. The estimation is done by the application programme Cosmos Works. Physical and mechanical properties of the materials are taken into account. The adequate mechanic-mathematical model, which is described in details in the first part of this investigation, is used for the aims of the study. The typical characteristics of the construction of a kind of circular saws are taken into account in the model. The circular saw is drawn in 3D by the application programme Solid Works and it is modelled with four nodes 3D finite elements. The results of this investigation prove the practical significance of the model. They point the possibilities for determinations of resonant regimes and they are a base for their detail studying.

Key words: circular saws, modelling, vibrations

1. INTRODUCTION

One of the main tasks in designing and measuring of the circular machines is to estimate in advance the danger of the resonance. Therefore, it is necessary to study frequencies of the natural vibrations of the circular saw. This requires simulative investigations in order to differ resonant regimes. The investigations are done on the base of the adequate mechanic-mathematical model which takes into account the typical characteristics in its construction and physical-mechanical characteristics of materials. The developed model of a kind of circular saw is described in details in the first part of this investigation. The circular saw is drawn in the 3D by the application programme Solid Works. After that a mash of four node 3D finite elements, shown on fig 1, is modelled by the programme Cosmos Works.

2. DIFFERENTIAL EQUATIONS

The differential equations which describe the free continuous vibrations of the circular saw are

$$\mathbf{M}.\ddot{\mathbf{q}} + \mathbf{C}.\mathbf{q} = 0, \qquad (1)$$

Where:

$\mathbf{q} = [q_1 \quad q_2 \quad \dots \quad q_n]^T$ is the vector of the generalized coordinates; (2)

$\mathbf{M}$ – the matrix, which characterizes the mass-inertial properties of the mechanical system;

$\mathbf{C}$ – the matrix, which characterizes the elastic properties of the mechanical system.

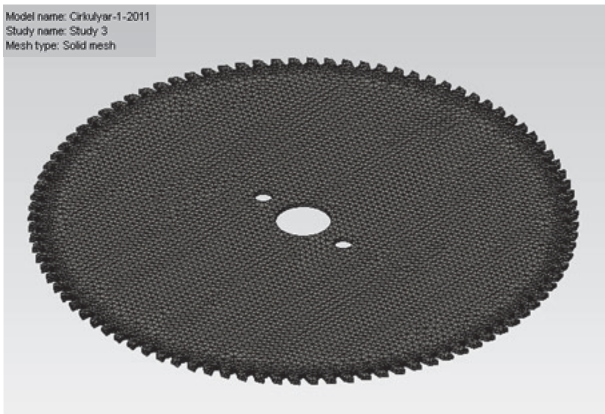


***Figure. 1** Circular saw, modeled by the mesh of finite elements*

The system of connected linear differential equations is obtained when the vibrations are small. Particular solutions of the system of the differential equations (1) are searched as:

$$\mathbf{q}_r = h_r . \sin(\omega_r . t + \varphi) , \quad (3)$$

where h_r is the amplitude of the small vibration on the generalized coordinate q_r with natural frequency ω_r, and φ is initial phase.

After differentiation of (3) and substituting in (1) it is obtained a system of linear algebraic equations:

$$\left| \mathbf{C} - \omega^2 . \mathbf{M} \right| . \mathbf{V} = 0 . \quad (4)$$

To determine the natural frequencies and the mode shapes, it is necessary to solve the task about finding of the natural values and the natural vectors of the equations (4). The satisfactory of the equations (4) requires the follows:

$$\det\left(\mathbf{C} - \omega^2 . \mathbf{M} \right) = 0 . \quad (5)$$

The roots of the characteristics equation determine the natural frequencies. The natural frequencies form the matrix of the natural values. It is:

$$\omega = diag \left\lfloor \omega_{r,r} \right\rfloor, \quad r = 1, 2, \ldots n . \quad (6)$$

The natural frequencies are determinate by (6):

$$f_r = \frac{\omega_{r,r}}{2.\pi} \ Hz . \quad (7)$$

The natural values of the system (5) determine the natural vectors. The modal matrix of the free vibrations is determined by the equations (4) and (5):

$$\mathbf{V} = \begin{bmatrix} V_{11} & V_{12} & \ldots & V_{1n} \\ V_{21} & V_{22} & \ldots & V_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ V_{m1} & V_{m2} & \ldots & V_{mn} \end{bmatrix} \quad i = 1 \ldots m; \quad j = 1..n , \quad (8)$$

Where V_{ij} are the unknown amplitudes of the nodes' moving by free vibrations. The natural frequencies and the mode shapes are determined by the known matrix, which characterizes the mass-inertial properties and the matrix that characterizes the elastic properties of the mechanical system.

3. NUMERICAL INVESTIGATIONS

The numerical investigations are done by modelling circular saw with finite elements. Physical-mechanical characteristics of materials are taken into account – they are shown in tables 1, 2 and 3. The estimation of the natural frequencies and mode shapes of the circular saw are done by the application programme Cosmos Works.

Table 1. *Model Information*

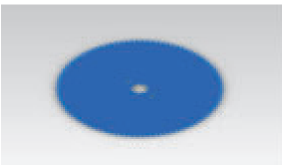
Document Name and Reference	Treated As	Volumetric Properties
Extrude1 	**Solid Body**	**Mass:1.09891 kg** **Volume:0.00013981 m^3** **Density:7860 kg/m^3** **Weight:10.7693 N**

Table 2. *Mesh Information*

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Jacobian points	4 Points
Element Size	3.62344 mm
Tolerance	0.181172 mm
Mesh Quality	High

Table 3. *Mesh Information - Details*

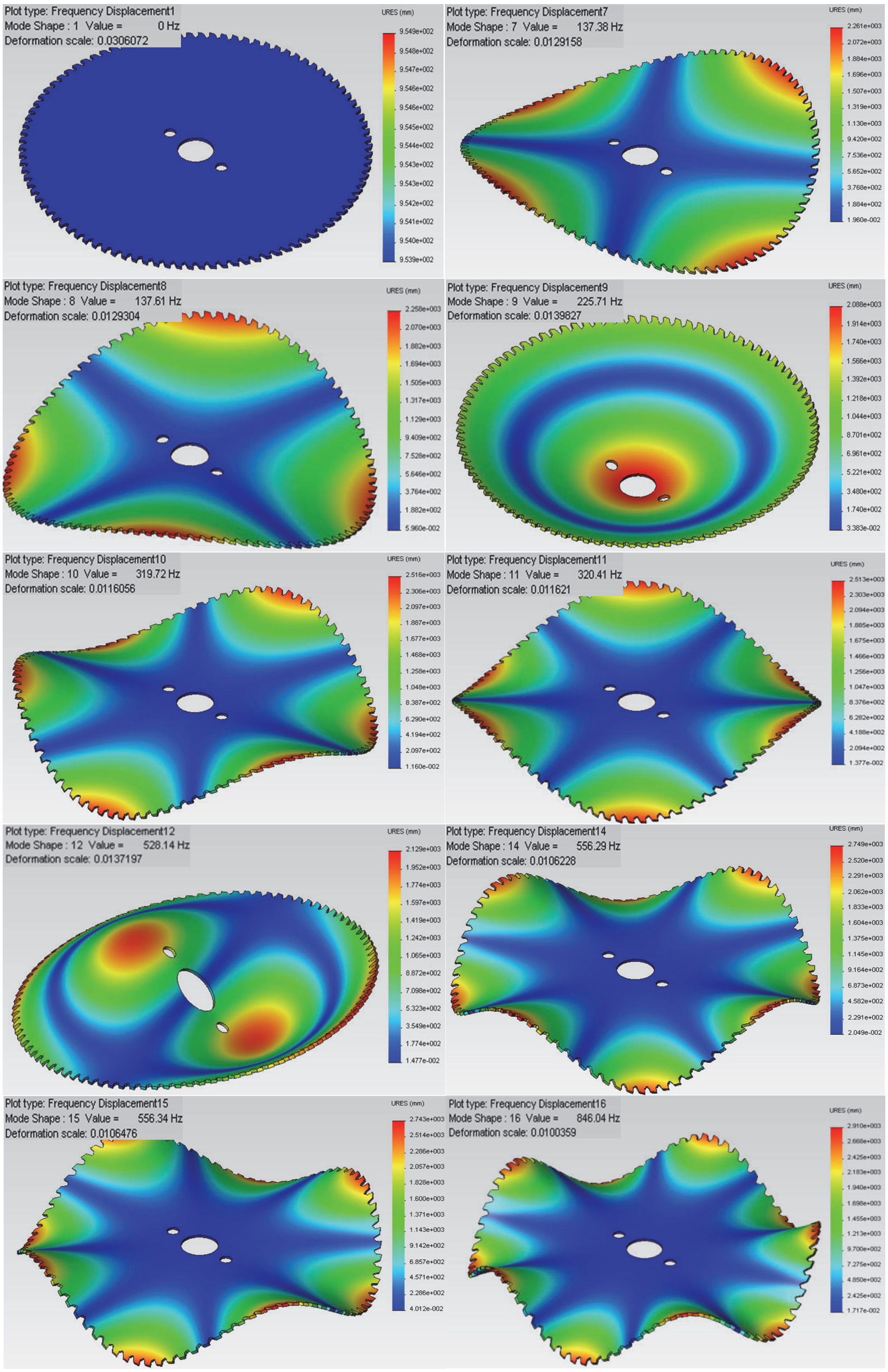
Total Nodes	80205
Total Elements	39861
Maximum Aspect Ratio	22.07
% of elements with Aspect Ratio < 3	91.5
% of elements with Aspect Ratio > 10	0.00251
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:04:00

4. RESULTS

The first 30 natural frequencies and mode shapes of the studied circular saw are determined. The estimated natural frequencies are shown in the table 4. The results, which illustrate only some of the natural modes, are included because of the limited size of the article. They are shown on fig. 2 and their characteristics and shown in the table 5.

Table 4. *Mode List*

Frequency Number	Rad/sec	Hertz	Seconds
1	0	0	1e+032
2	0	0	1e+032
3	0	0	1e+032
4	0	0	2869
5	0	0	2056.6
6	0	0	1863.7
7	863.2	137.38	0.0072789
8	864.63	137.61	0.0072669
9	1418.2	225.71	0.0044304
10	2008.9	319.72	0.0031277
11	2013.2	320.41	0.003121
12	3318.4	528.14	0.0018934
13	3322	528.71	0.0018914
14	3495.3	556.29	0.0017976
15	3495.6	556.34	0.0017975
16	5315.8	846.04	0.001182
17	5317.5	846.31	0.0011816
18	5665.8	901.74	0.001109
19	5673.9	903.03	0.0011074
20	6265.7	997.21	0.0010028
21	7453.8	1186.3	0.00084296
22	7456	1186.7	0.00084271
23	8583.2	1366.1	0.00073203
24	8589.4	1367	0.0007315
25	9563.4	1522.1	0.000657
26	9583.6	1525.3	0.00065562
27	9890.7	1574.2	0.00063526
28	9901.5	1575.9	0.00063457
29	11884	1891.3	0.00052873
30	11891	1892.6	0.00052839


Plot type: Frequency Displacement1
Mode Shape : 1 Value = 0 Hz
Deformation scale: 0.0306072
URES (mm)
Plot type: Frequency Displacement7
Mode Shape : 7 Value = 137.38 Hz
Deformation scale: 0.0129158
URES (mm)
Plot type: Frequency Displacement8
Mode Shape : 8 Value = 137.61 Hz
Deformation scale: 0.0129304
URES (mm)
Plot type: Frequency Displacement9
Mode Shape : 9 Value = 225.71 Hz
Deformation scale: 0.0139827
URES (mm)
Plot type: Frequency Displacement10
Mode Shape : 10 Value = 319.72 Hz
Deformation scale: 0.0116056
URES (mm)
Plot type: Frequency Displacement11
Mode Shape : 11 Value = 320.41 Hz
Deformation scale: 0.011621
URES (mm)
Plot type: Frequency Displacement12
Mode Shape : 12 Value = 528.14 Hz
Deformation scale: 0.0137197
URES (mm)
Plot type: Frequency Displacement14
Mode Shape : 14 Value = 556.29 Hz
Deformation scale: 0.0106228
URES (mm)
Plot type: Frequency Displacement15
Mode Shape : 15 Value = 556.34 Hz
Deformation scale: 0.0106476
URES (mm)
Plot type: Frequency Displacement16
Mode Shape : 16 Value = 846.04 Hz
Deformation scale: 0.0100359
URES (mm)

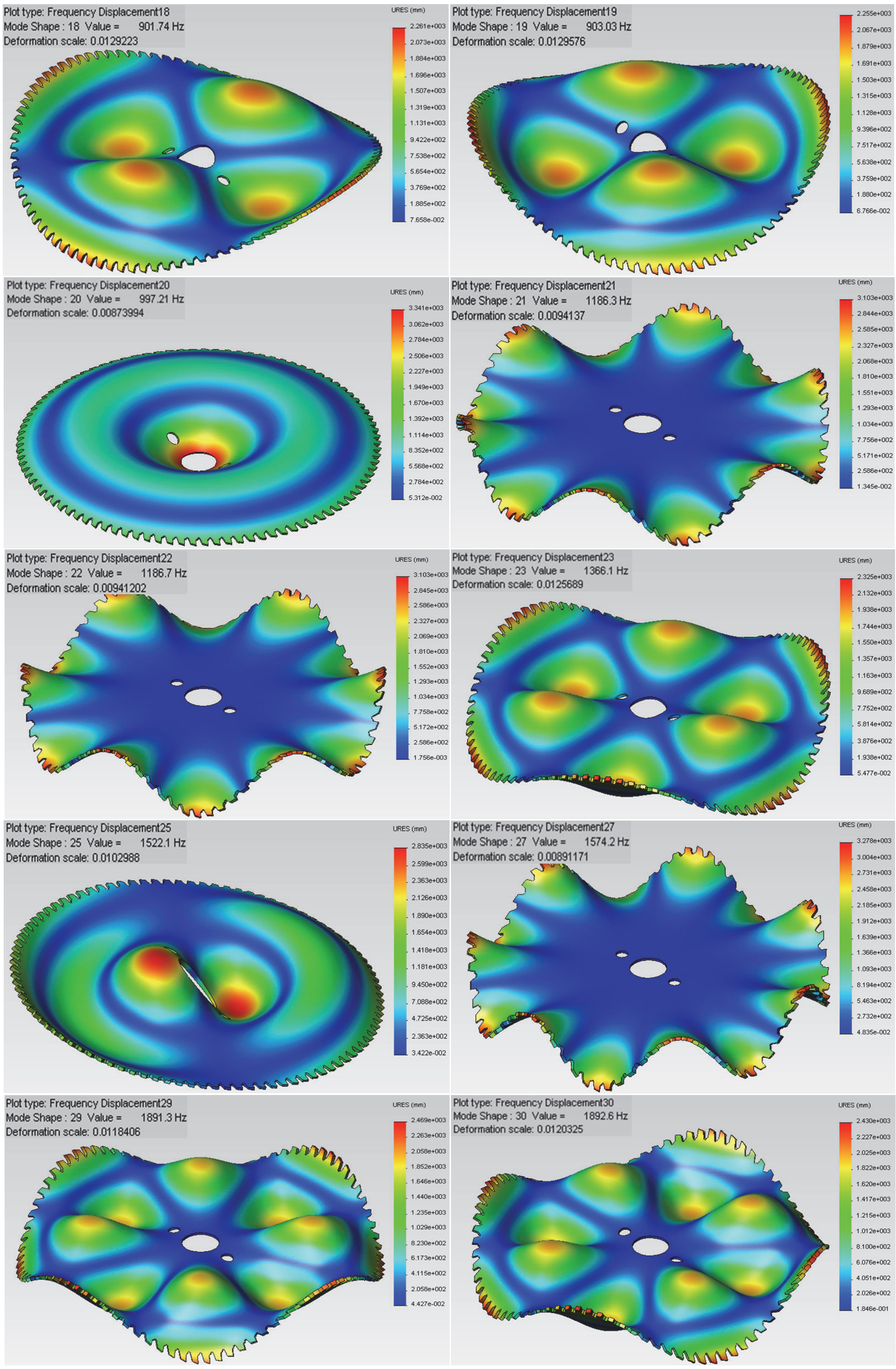


***Figure 2.** Mode Shapes*

Table 5. *Characterization of the natural frequencies*

Name	Type	Min	Max
Displacement 1	URES: Resultant Displacement Plot for Mode Shape: 1 (Value = 0 Hz)	953.934 mm, Node: 1	953.934 mm, Node: 1
Displacement 7	Mode Shape: 7 (Value = 137.383 Hz)	0.019604 mm, Node: 34027	2260.75 mm, Node: 797
Displacement 8	Mode Shape: 8 (Value = 137.61 Hz)	0.0595973 mm, Node: 65269	2258.2 mm, Node: 2309
Displacement 9	Mode Shape: 9 (Value = 225.713 Hz)	0.0338278 mm, Node: 36012	2088.1 mm, Node: 68501
Displacement 10	Mode Shape: 10 (Value = 319.719 Hz)	0.0115955 mm, Node: 55717	2516.1 mm, Node: 976
Displacement 11	Mode Shape: 11 (Value = 320.406 Hz)	0.0137685 mm, Node: 37018	2512.75 mm, Node: 832
Displacement 12	Mode Shape: 12 (Value = 528.14 Hz)	0.0147705 mm, Node: 54165	2129.23 mm, Node: 1948
Displacement 14	Mode Shape: 14 (Value = 556.294 Hz)	0.020492 mm, Node: 43971	2749.05 mm, Node: 1391
Displacement 15	Mode Shape: 15 (Value = 556.34 Hz)	0.040122 mm, Node: 53971	2742.63 mm, Node: 1066
Displacement 16	Mode Shape: 16 (Value = 846.04 Hz)	0.0171691 mm, Node: 80038	2910 mm, Node: 1858
Displacement 18	Mode Shape: 18 (Value = 901.74 Hz)	0.0765767 mm, Node: 33016	2261.2 mm, Node: 1588
Displacement 19	Mode Shape: 19 (Value = 903.025 Hz)	0.0676639 mm, Node: 33426	2255.02 mm, Node: 940
Displacement 20	Mode Shape: 20 (Value = 997.209 Hz)	0.0531191 mm, Node: 31814	3340.76 mm, Node: 80080
Displacement 21	Mode Shape: 21 (Value = 1186.3 Hz)	0.0134453 mm, Node: 43006	3102.54 mm, Node: 1913
Displacement 22	Mode Shape: 22 (Value = 1186.65 Hz)	0.00175568 mm, Node: 80192	3103.1 mm, Node: 689
Displacement 23	Mode Shape: 23 (Value = 1366.06 Hz)	0.0547663 mm, Node: 36785	2325.39 mm, Node: 905
Displacement 25	Mode Shape: 25 (Value = 1522.06 Hz)	0.0342162 mm, Node: 50021	2835.02 mm, Node: 56742
Displacement 27	Mode Shape: 27 (Value = 1574.16 Hz)	0.0483514 mm, Node: 59101	3277.58 mm, Node: 1355
Displacement 29	Mode Shape: 29 (Value = 1891.34 Hz)	0.0442699 mm, Node: 42536	2469.06 mm, Node: 977
Displacement 30	Mode Shape: 30 (Value = 1892.56 Hz)	0.184585 mm, Node: 58744	2429.72 mm, Node: 1516

5. CONCLUSION AND FUTURE INVESTIGATIONS

The paper presents the methodic and results of the simulative investigations of the circular saw. The natural frequencies and mode shapes of the studied circular saw are obtained. The estimation is done by a current application programme, taking into account the typical characteristics in the construction of a kind of circular saws and the physical - mechanical characteristics of their materials. The results of the investigations prove practical significance of the developed mechanic-mathematical model and the methods for study of the circular saw. They pointed the possibilities for the investigations of the class of circular saws with a complicated constructive scheme. These investigations are an object of the following parts of this work.

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HEAT RESISTANCE OF FURNITURE SURFACES FINISHED WITH OIL AND WAX

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ABSTRACT

Wood surface dressing may be done by different coats, and the choice depends on many factors such as technological, aesthetic, economic and ecological ones. Growing consciousness of preserving the environment has crucially influenced on growth of application natural materials for wood surface dressing - oils and waxes.

Application of oils and waxes provides wood to keep its natural appearance, with simultaneous protection from different effects which may cause degradation and deterioration.

In this work, we investigated dry heat resistance of beech (*Fagus silvatica* L.) surface dressed with linseed oil and wax. Surfaces coated with beeswax are less resistant to heat than surfaces coated with linseed oil.

Key words: surface dressing, solid wood, linseed oil, beeswax, heat resistance

1. INTRODUCTION

Wood surface dressing by natural materials is of current interest again. People are more and more longing for living in natural surroundings, so a trend towards being surrounded by solid wood dressed with natural materials is more emphasized. Advantages of natural materials for wood surface dressing open new possibilities form market disposal, i.e. better sale (Jaić and Živanović, 2000).

Although market demand for products dressed with natural materials is more emphasized, many old techniques for surface dressing together with array of natural materials have been forgotten. Returning, i.e. using natural materials again under present technology conditions and modern synthetic coatings, poses a question of comparing their features in relation to present most used dressing materials.

Among natural materials, linseed oil and beeswax, previously used largely, are being most often used for wood surface dressing at present. So their comparison with up-to-date dressing was of interest, as nowadays most often used synthetic PU dressing for gaining valuable information on advantages and disadvantages of both materials, such as e.g. dressed surface duration, on the one hand, and esthetic and ecological values along with easy repair after damaging on the other hand.

2. OILS AND WAXES

2.1 Linseed oil

Surface dressing with oil presents one of the oldest procedures for protection and enriching wood surface during which linseed oil was most often used. The beginning of linseed oil application goes back to XVII century, and then it was intensively used in XIX century after which its consumption was brought to minimum. In the past few years, one can notice revival of applying linseed oil for dressing, most often, solid wood (Hocker, 2003).

Linseed oil is golden yellow drying oil, made from flax seeds, and it is light yellow when bleached, and greasy, too. It is obtained on cold or hot in presses by extracting with organic solvents. Cold strained oil is darker than hot strained oil, and it is worse by its quality. The name "linseed oil" is an abbreviated form of flax seeds oil.

Linseed oil contains higher fat acids with two or more double bonds. By binding oxygen from the air, double bonds break and transfer (if they are conjugated), oxygen binds to them and transversal peroxide bridges are formed making oil web and making it stronger. Thin hardened oil films made in this way are tough, elastic and waterproof. Linseed oil drying is auto oxidation and polymerization of oil in the air. Polymerization is performed by fat acid chains connecting, which gives necessary toughness and firmness to the film. Made film is called linoxine, at which oil absorbs 15-20% of air oxygen, and made film weights more by this amount from applied oil itself. Because of this, these oils are bases for all oil coats. Linseed oil is due to linol and linolen acid, which oxidizes easy in the air, the most appropriate and most applied drying oil. Because of this, when enriched with substances for accelerated drying, linseed oil is a basis for making varnish**.**

2.2 Beeswax

Waxes may be defined as wax type materials with melting temperature higher than body temperature (37˚C), and lower than water boiling temperature (100˚C). Therefore, the expression "**wax"** may be used widely to describe wax type materials (Allen, 1995). From chemical point, waxes are defined as esters of heavy weight molecule monohydroxile alcohols and higher fat acids. Their general formula is **R—COO—R** and they are usually mixtures of esters. Nevertheless, they do not always have to be esters, particularly if they are paraffin waxes which represent mixture of heavy weight molecule (mostly over C18) carbon hydroxide (paraffin). Paraffin waxes are made by crude oil distillation. Melting point of these waxes is between 35˚C and 38˚C. Otherwise, waxes consist of mixed normal alcohol esters and fat acids with even number of carbon atoms (usually C_{32}-C_{34}).

Beeswax is made of alcohols and acids with smaller number of carbon atoms (C_{26}-C_{28}). Because of that, it is melted at lower temperatures, between 60˚C and 82˚C.

Waxes form very good protective layer on the wood surface which is more resistant to water comparing to other natural products. They have particularly distinctive wood surface isolation (sealing) property which emphasizes protection from diffused moisture coming from the wood. Waxes are relatively easy and simply applied onto surface where they keep natural effect of the wood, simultaneously emphasizing wood texture.

Waxes show certain shortages which mainly regard to their firmness (waxes are soft), which means that protective layer may easily be damaged by mechanical activity (scratching). This shortage may be compensated by relatively easy damage repair on the surface (by adding one more wax layer). Until repair is done, wood surface remains sensitive to water action (and other liquids) which might have degrading effect. Forming very thin layer on the surface presents a shortage of applying wax for wood protection, and that layer is not enough for complete wood protection from water and other liquids activity. Dust and other dirts relatively easy embed in wax layer, as well as in wood pores, which negatively influence on aesthetic appearance of dressed surface.

3. CHEMICAL BOND BETWEEN DRESSING AND BASE

Besides easy coating, one of basic conditions that dressing has to meet is to make good chemical interaction with the base. This interaction means to spread dressing over wood surface by following rough spots and roughness of base. Dressing should also partly enter wooden tissue capillaries to provide hardened dressing "locking" and good physical adhesion. Much more important aspect of adhesion is forming chemical and physical bonds between dressing and wood as base. Two basic types of made connections are chemical covalence bonds and physically chemical bond of hydrogen bond type and Van der Waals' intermolecular attraction forces (Kollmann, 1975).

Covalence bonds connect base and dressing into firm and made connection is waterproof. Hydrogen bridges and Van der Waals' forces are 10-20 times weaker than covalence bond, but there are not many of them, so they are capable to make strong binding of dressing with the base. Wood is polar material and in a chemical way it goes well with polarized molecules and make covalence physically chemical bonds with them. Besides these bonds, wood enters chemical reactions with polyurethane and makes covalence bonds which provide particular firmness and resistance to this connection (Figure 1).

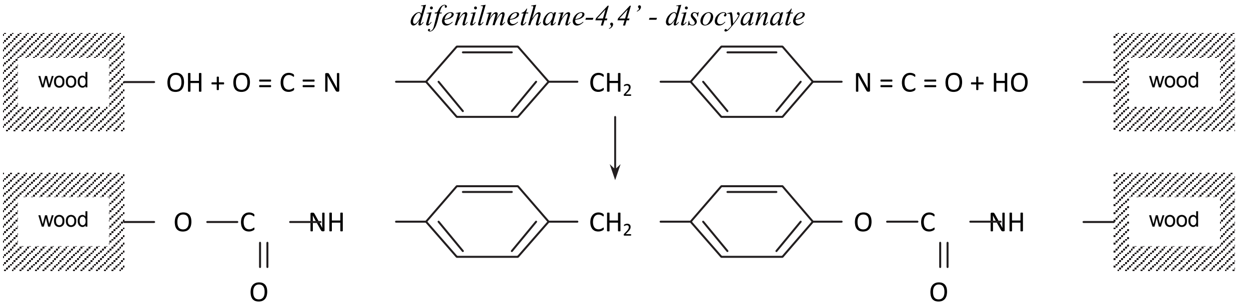

Figure 1. *Making covalence bonds – reaction between polyurethane and wood*

It is without doubt that PU-dressing makes both bond types with wood and therefore firm and long-lasting adhesive connection. On the other side, weak polar hydrophobic dressings, like beeswax and linseed oil, cannot make covalence bond with wood tissue, but due to containing ester and hydroxyl groups they can make hydrogen bridges with wood (Figure 2) as well as Van der Waals' i.e. London's dispersion intermolecular attraction forces.

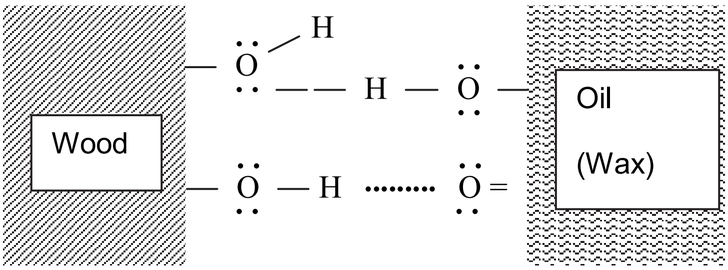

Figure 2. *Possible appearance of hydrogen bridges between wood and oils, i.e. waxes*

4. OILS AND WAXES APPLICATION

4.1 Linseed oil preparation and application

In order to determine quality of surface dressing, preparation of samples made from beech (*Fagus silvatica* L.) was done by grinding, and after that linseed oil (manufactured by "Liberon" – France) was applied onto samples. Oil is delivered ready for application. Parameters for dressing are shown in Table 1.

Table 1. *Conditions for linseed oil application*

PARAMETER	VALUE
APPLICATION MANNER	Manual cloth rubbing
WOOD DAMPNESS	12 %
OIL DENSITY	0.92 g/cm^3
OIL VISCOSITY	18 s (F4/20 ^{0}C)
DRESSING RATE IN ONE LAYER	10 g/m^2
PERIOD BETWEEN LAYERS	Overnight (t > 12^h)
TOTAL NUMBER OF LAYERS	3
AIR TEMPERATURE IN THE ROOM	21 ^{0}C
HUMIDITY OF AIR IN THE ROOM	60 %

Well soaked cloth (linen) was used for oil application. It is necessary to rub oil strongly onto surface, while it is important to distribute oil regularly so the surface would be evenly dressed. Otherwise, blot spots may be made on the surface. Cloth rubbing was done in circular movements at the beginning, and then oil distribution was continued by following fiber direction. Certain quantity of heat is released during application, due to friction, which helps deep penetration of oil into the wood.

Dressed samples are left to dry over night. Before applying new layer of oil, surface was grinded (abrasive paper grading N°320).

4.2 Beeswax preparation and application

Beeswax manufactured by “Liberon” (France) was used for investigation. Wax is delivered ready for application, so it does not need preparation before it.

Conditions for beeswax application are shown in Table 2.

Table 2. *Conditions for beeswax application*

PARAMETER	VALUE
APPLICATION MANNER	Manual cloth rubbing
WOOD DAMPNESS	12 %
OIL DENSITY	0.90 g/cm^3
DRESSING RATE IN ONE LAYER	10 g/m^2
PERIOD BETWEEN LAYERS	Overnight (t > 12^h)
TOTAL NUMBER OF LAYERS	2
WORKING TEMPERATURE IN THE ROOM	21 ^{0}C
HUMIDITY OF AIR IN THE ROOM	60 %

Soft cloth was used for rubbing wax onto prepared samples. First, wax was applied transversely, then longitudinally in relation to fiber direction (wood structure). In both layers, application was regular so surface was uniformly dressed (coated). Dressed surfaces are left overnight (t > 12^h) to dry, and then polished with brush made of horse hair. Wax dressing demands applying each layer thin (thick layer forms “blurred" surface appearance) and careful rubbing each layer with sharp hair brush.

5. DETERMINING HEAT RESISTANCE

During exploration surface dressed wood products are exposed to heat in two ways: by raising air temperature or by direct contact with hot surface. Dressing reaction to heat coming from hot objects is important for interior products (Jevtić, 2005).

Determining dry heat resistance was done according to JUS D.E8.220 standard.

The procedure of determining surface resistance to dry heat is based on placing heated object on tested surface where it stays for 30 minutes and observing changes made at investigation temperature (Jaić, Živanović, 1993).

Aluminium pot with even grinded bottom is placed on the base, with bottom thickness of 4mm, height and inner diameter of 140mm, where 500g of mineral oil is and it is heated up to determined temperature: 85, 100, 120 or 140 ^{0}C. After being heated, the pot is placed on dressing surface where it stays for 30 minutes. 24^h after removing the pot, damages on dressing are observed, such as e.g. color change, gloss change, blisters and other. Observing is done parallel and normal to fiber direction.

Dressing resistance to dry heat is graded on the basis of one of the worst among three investigated spots, and according to classification shown in Table 3.

6. RESULTS

The results of investigating dry heat resistance of beech dressed with linseed oil and beeswax are presented in Table 4.

Table 3. *Classification of dressing resistance to dry heat*

GRADE	CHANGE ON SURFACE
5	Without damages (no apparent changes)
4	Small gloss change, apparent only when light source reflects on acting surface or nearby
3	Poorly noticed blots, apparent when looked from more directions
2	Highly noticed blots, there is a change in surface structure
1	Highly noticed blots, protective dressing partially or completely degraded

Table 4. *The results of investigating dry heat resistance of surface*

Dressing manner	Temperature (ºC)			
	85	100	120	140
Resistance gradation				
Linseed oil	5	4	3	2
Beeswax	2	2	1	1

Wood surfaces dressed with linseed oil present the best resistance to dry heat at temperatures of 85˚C and 100˚C (grades **5** and **4**), i.e. there are no apparent changes on the surface, although insignificant gloss changes occur. Rising investigation temperature to 120˚C and 140˚C, regardless to dressing manner (type and number), resistance to dry heat is lessen, so surfaces are graded with **3** and **2**, i.e. significant changes on surface occur, which manifest themselves by gloss and color changes, and apparent mark from heated object occurs (Figure 3).

Surfaces dressed with beeswax are sensitive to temperature so the lowest applied temperatures (85˚C and 100˚C) cause significant gloss and color changes, while apparent mark of pot bottom occurs on the surface, so resistance is graded with **2** (very low resistance). At temperatures of 120˚C and 140˚C significant color changes occur, and distinctive mark occurs too, so the surface was graded with **1** (Figure 4).

Figure 3. *Surface changes after heat activity (beech, 2 x oil, t = 140˚C)*

Figure 4. *Surface changes after heat activity (beech, 2 x wax, t = 140˚C)*

7. CONCLUSION

Dry heat activity on dressed surfaces makes damages of different intensity. Beech surfaces dressed with linseed oil are more resistant than those dressed with beeswax.

The best resistance of beech surface dressed with linseed oil is gained at temperatures up to 100ºC, while raising temperature to 120ºC and 140˚C significantly lowers surface resistance which is manifested by changing dressing color and gloss, while clearly noticeable marks made by heated body appear on the surface.

The resistance of beech surface dressed with beeswax is significantly poorer than that dressed with linseed oil, even at the least applied temperature (85ºC).

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AESTHETIC AND STRENGTHS CHANGES IN THERMALLY TRETAED BEECH FALSE HEARTWOOD (*Fagus Sylvatica* L.)

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ABSTRACT

This paper discuses the aesthetic changes and some of the mechanical changes in native beech wood (*Fagus sylvatica* L.) and beach wood which has developed false heartwood, before and after being thermally treated. The aesthetic properties, colour and texture are determined visually, whereas some of the mechanical properties which have been tested are pressure strength, bending strength and the elasticity modulus under stress (when bending wood).

Discolouration, also called false heartwood, becomes identical with the colour of native beech after being treated at 180^0C, and at 230^0C the colour and texture get dark. Pressure strength of native beech wood increases after thermal treatment, but it is lower than in beech false heartwood. After thermal treatment there are no significant differences in bending strength and elasticity modulus of native beech wood and beech false heartwood. Thermal treatment at 180^0C drastically reduces the bending strength, but increases the elasticity modulus.

Key words: beech wood, false heartwood, thermal treatment, color, texture, pressure strength, bending strength, elasticity modulus.

1. INTRODUCTION

Beech is a typical diffusely porous tree. Deviations in color and texture in the center of the log is common for beech wood, and in some cases it occurs along the whole length of the log. This phenomenon is called false heartwood, and the result of this is reduction in wood quality. Changes are not only aesthetic. In comparison with native beech wood, changes are manifested through physical and mechanical properties of the wood. In later stages, false heartwood is usually rotten.

Thermal treatment of the wood is a process of controlled pyralisis. From technological aspect, thermally treated wood can be: Thermo-S, treated at temperatures up to 185°C; and Thremo-D, treated at temperatures up to 230°C. The first esthetic changes in color hue and texture are manifested at temperature above 120°C. Alongside aesthetic changes, some physical and mechanical changes also occur.

Discoloration of beech false heartwood is offset with wood steaming. Treatments of the wood with high temperatures darken both native beech and beech false heartwood. Beside color changes, the mechanical changes are also interesting, such as the pressure strength, bending strength and the elasticity modulus.

2. RESEARCH TO DATE

False heartwood phenomenon in beech wood occurs as a result of oxygen penetrating the basic structure elements of older beech trees (Zycha 1948). In those tree parts where there is low percentage of water, there is reduced vitality of the parenchyma cells. In contact with living parenchyma tissue, the oxygen starts to transform the carbohydrates into phenol substances (Bauch and Koch 2001).

Cutting off water flow in tree substantially reduces the vitality of the parenchyma tissue (Necesany 1966). This leads to reduction of the physiological characteristics of the tree (Ziegler 1968), decomposition of the dissolvable carbohydrates (Dietrichs 1964) and transformation of the substances into heartwood substances.

False heartwood in beech tree (Shokich an Popovich 2002) is considered to be an aesthetic mistake, a change of colour in the cross section of the tree trunk into dark red, but it does not decrease the physical properties of the wood and it has similar mechanical properties as a healthy tree.

Gradual increment in temperature changes some of the essential properties of wood (Stamm et al. 1946, Burmester 1973, Giebeler 1983). The original experiments with thermal wood treatment were done in Europe: Holland (de Ruyter 1989, Boonstra et al. 1998, Tjeerdsma et al. 1998b, Militz and Tjeerdsma 2000), France (Dirol and Guyonnet 1993, Vernois 2000), Germany (Sailer and Rapp 2000, Rapp et al. 2000) and Finland (Viitanen et al. 1994, Syrjänen et al. 2000, Jämsä and Viitaniemi 1998).

Thermal wood treatment happens at temperatures of 120 to 280°C. The thermal treatment mode depends on the type of wood, humidity percentage, dimensions, type of process, the desired degree of changes, the consistency of biodegradable processes, the dimensional consistency of the wood, etc. (Emmler and Scheiding, 2007). The shift in colour is due to degrading hemicellulose, cellulose, lignin and the extractible substances (Tjeerdsma 2003, Sundqvist 2004, Windeisen 2009, Bekhta and Neimz 2003, Kocaefe 2008, Mitsui 2001, Johansson and Moreu 2006, Esteves 2008, Hale 2009, Toung and Li 2009). At temperatures from 140 to 200°C wood pressure strength increases, sometimes as much as by 30% (Damiano 1999, Santos 2000). But that is not the case with all physical properties; bending strength, for instance, decreases by 30% (Viitaniemi 1996), and according to some authors (Bengston, Jermer, Brem 2002), there is even a 50% drop.

3. THE GOAL OF THIS STUDY

This study is primarily focused on change of aesthetic as a result of change in color and texture of native beech wood and false heartwood, before and after thermal treatment. Subjects of interest are also some mechanical properties, such as pressure strength, bending strength and the elasticity modulus under stress (bending), and the impact thermal treatment has on these parameters.

The goal of this study is to contribute to defining the properties, differences and changes in differences in thermally treated wood at 180°C and 230°C, with and without false heartwood.

4. MATERIALS AND METHODS

Experiments were made with samples of beech wood (*Fagus sylvatica* L.), which is a dominant tree type in the woods in the Republic of Macedonia. The samples were grouped in six groups: three groups of native beech wood and three of beech wood with false heartwood. The samples were prepared in compliance with ISO 3133 standard and a sample measuring 20x20x300 mm, from which later smaller sample pieces measuring 20x20x30 mm were cut off.

Thermal treatment is performed as an oxidation process. A chamber with an opening was used for release of byproducts (acetic acid, furfural, etc.). Two temperature modes were applied, the first one with a maximum temperature of up to180°C, and the second one with a maximum temperature of up to 230°C. The temperature modes are shown in figure 1.

The aesthetic changes of wood are determined visually, they are illustrated with photographs and descriptively presented.

Pressure strength (σ_{pr}) is determined by ISO 3132. It was calculated as a product of the maximum strength *(Pmax)* in relation to the cross section of the sample, using the formula:

$$\sigma_{pr} = \frac{P_{\max}}{b \cdot h} \text{ [MPa]}$$

in which: b – width of the sample (cm),
h – height of the sample (cm).

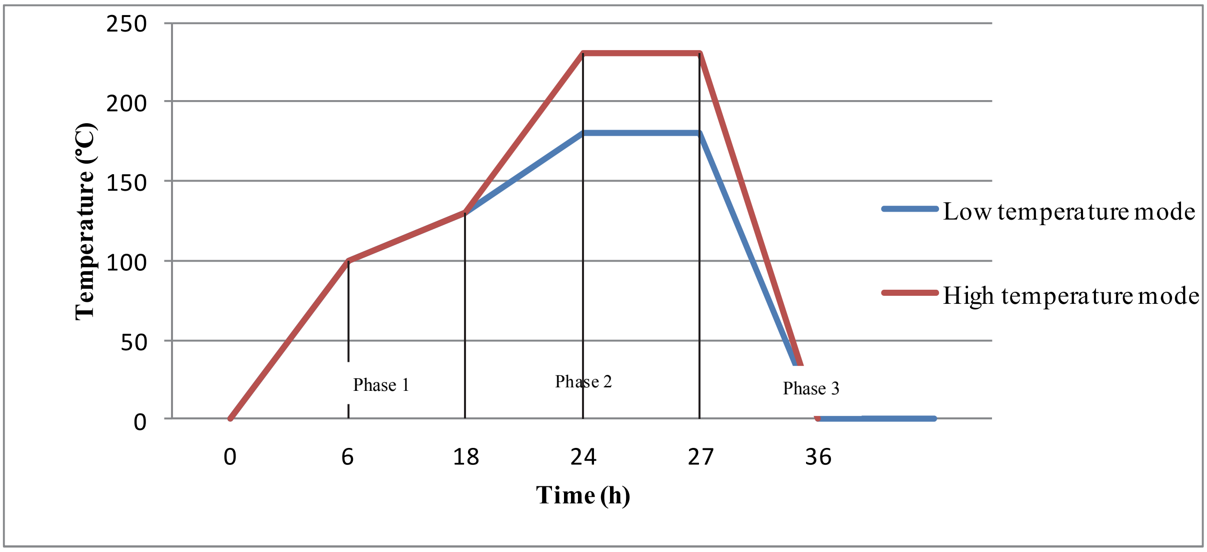

Figure 1. *Wood thermal treatment modes*

Phase 1. Thermal buildup and high-temperature-caused desiccation.
Phase 2. Thermal treatment.
Phase 3. Cooling and conditioning.

Bending strength (σ_{sv}) was measured and calculated in compliance with ISO 3133 standard, using the following equation:

$$\sigma_{sv} = \frac{3P \cdot l}{2b \cdot h^2} \text{ [MPa]}$$

Because of unequal wetness of the sample pieces *(W),* values calculated for bending strength (σ_{sv}) were corrected with a coefficient ($\alpha = 0,02$) and the bending strength was calculated at 12% wetness (σ_{cv12}). This value was considered final.

$$\sigma_{sv12} = \sigma_{sv}[1 + \alpha(W - 12)] \text{ [MPa],}$$

Elasticity modulus under stress (when bending wood) (E_{sv}) was calculated in compliance with ISO 3349 standard, by flexion (f) measured in cm, applying the following formula.

$$Esv = \frac{P \cdot l^3}{4 \cdot f \cdot b \cdot h^3} \text{ [MPa]}$$

5. RESULTS AND DISCUSSION

It is commonly known that beech wood is mostly white with yellowish or reddish hues. The texture reveals a weak differentiation between rings, i.e. summer and winter growth zones. The rings are slightly more differentiated at a tangential cross section and, compared to the radial cross section, the texture is slightly more colourful. The parenchyma – the heart rays, are slightly darker, at radial section being spindle-like and evenly distributed, while their tangential cross section features colourfulness of the texture.

From an aesthetic point of view, false heartwood in beech trees is fairly obvious. False heartwood colour varies from grey-reddish to dark brown, often with lighter or darker nuances and definitely colourful texture.

***Figure 1**. Samples of native and false heartwood beech*

Thermal treatment of native beech at 180^{o}C changes the colour of the wood into brown. Colourisation is uneven. It depends on the type of the cross section and accordingly, colourfulness is typical mainly with radial and tangential cross sections. On the other hand, thermal treatment of false heartwood beech, regardless the cross section, significantly reduces the differences in colour and texture.

After being thermally treated at 180^{o}C, the aesthetic irregularity in native beech wood and false heartwood beech, are drastically reduced, i.e. there is equalization of the colour and texture of thermally treated native beech and false heartwood beech. Thermal treatment at 230^{o}C colours the results into dark brown to black colour. Colour and texture become identical both with native beech wood and false heartwood beech.

***Figure 2**. Samples of native and false heartwood beech, before and after thermal treatment at 180^{o}C and 230^{o}C.*

Statistical values of pressure strength, bending strength and elasticity modulus, in both native and false heartwood beech, before and after thermal treatment, are shown in the table bellow, table 1.

From the tests performed, it is obvious that pressure strength is a property by which native beech distinguishes itself from heartwood beech. Mean values show that false heartwood beach has by 7.7% higher strength than native beech wood. Some of these measurements are in accordance with relevant literature (Pejovski 1966, Nacevski 1994, Wagenfuhr 2000). Statistically significant differences were also measured after thermal treatment at 180°C, at which false heartwood beech has by 4.8% higher pressure strength than native beech wood, and after thermal treatment at 230°C, the difference reaches 14.6%.

Table 1. *Statistical values of strength properties of native and false heartwood beech, before and after thermal treatment.*

No.	Property tested	Statistical indicator	Native beech wood	Native beech at 180°C	Native beech at 230°C	False heartwood	False heartwood at 180°C	False heartwood at 230°C
1	2	3	4	5	6	7	8	9
1.	**Pressure strength (MPa)**	x (MPa)	53,7	57,0	50,2	58,2	59,9	58,8
2.		σ (MPa)	3,4	4,9	5,4	3,4	3,8	3,9
3.		v (%)	6,3	8,5	10,7	5,8	6,3	6,6
4.	**Bending strength (MPa)**	x (MPa)	110,4	72,3	/	106	79	/
5.		σ (MPa)	11,3	14,7	/	16,9	21,1	/
6.		v (%)	10,23	20,3	/	15,94	26,7	/
7.	**Elasticity modulus (MPa)**	x (MPa)	10167	14781	/	10929	14321	/
8.		σ (MPa)	1219	2054	/	1297	1541	/
9.		v (%)	12	13.9	/	11.8	10.7	/

Thermal treatment affects pressure strength in native beech wood. When thermally treated with temperatures up to 180^{0}C, pressure strength in native beech wood is significantly increased by 5.7%. Relevant literature authors (Viitaniemi 1996, Bonstra 2007) suggest that increase in pressure strength can reach even 30%. Thermal wood treatment with temperatures ranging from 140 to 200°C can lead to an increase in some strength properties of the wood (Dmianto 1999, Santos 2000).

Higher temperature treatment, performed at 230°C, affects pressure strength of native beech wood inversely proportional and reduces it. After thermal treatment of native beech wood at 230°C, its pressure strength drastically drops and is by 6,5% lower that the initial value These changes are of statistical importance. The decrease in pressure strength in native beech wood is due to drastic drop in volume mass at temperatures exceeding 200^{0}C, which is a perfect indicator of the quality of thermally treated wood (Seborg 1953, Stamm 1956, Rusche 1973 Fung 1974).

On the other hand, thermal treatment does not affect pressure strength of false heartwood beech. Pressure strength does not change after thermal treatment at 180°C and 230°C, i.e. the recorded mean values changes are minimal and have no statistical significance. In conclusion, thermal treatment at 230°C of false heartwood beach does not affect pressure strength.

Native beach wood and false heartwood beech differ in their bending strengths. The mean value of bending strength in native beech wood is by 3.9% higher than the bending strength of false heartwood beech. The significance coefficient does not show any difference between the bending strength of native beech wood and false heartwood beech. The values measured for bending strength are within the limits of values found in relevant literature (Pejovski 1966, Nacevski 1994, Wagenfuhr 2000). After thermal treatment at 180°C, bending strength declines. The values differences are statistically important. Native beech wood shows a drop of the bending strength by 34.5%, but this value is substantially lower in the case of false heartwood beech, being 25%. In addition, the mean value of bending strength of treated beech wood is now by 9% lower than in false heartwood beech.

Besides, low importance factor indicates that there are no differences in bending strength between thermally treated beech wood and thermally treated false heartwood beech.

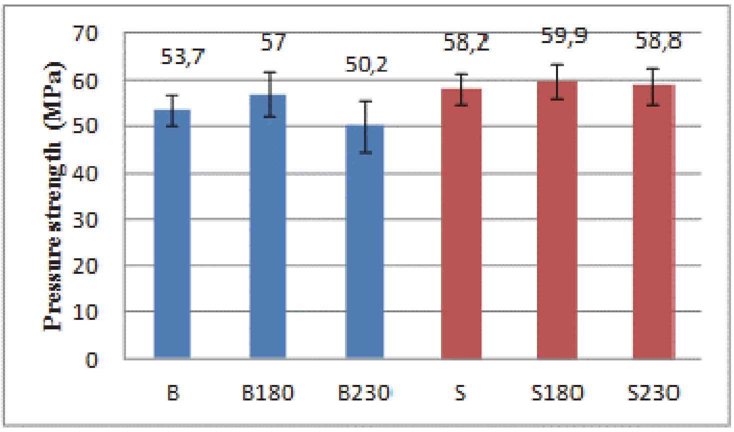

Figure 3. *Bar chart of pressure strength in native beech wood and false heartwood beech, before and after thermal treatment at 180°C and 230°C.*

B – beech wood, B_{180} –beech wood thermally modified at 180°C, B_{230} –beech wood thermally modified at 230°C, S – false heartwood, S_{180} – false heartwood thermally modified at 180°C, S_{230} –false heartwood thermally modified at 230°C

The results measured are within those presented in relevant literature. Thermal treatment of wood causes a decrease in bending strength by up to 30% (Viitaniemi 1996), and in some cases, according to other authors (Bengston, Jermer и Brem 2002), by up to 50%. Bending strength of false heartwood beech is also within the limits relevant for beech wood (Wagenfuhr 2000).

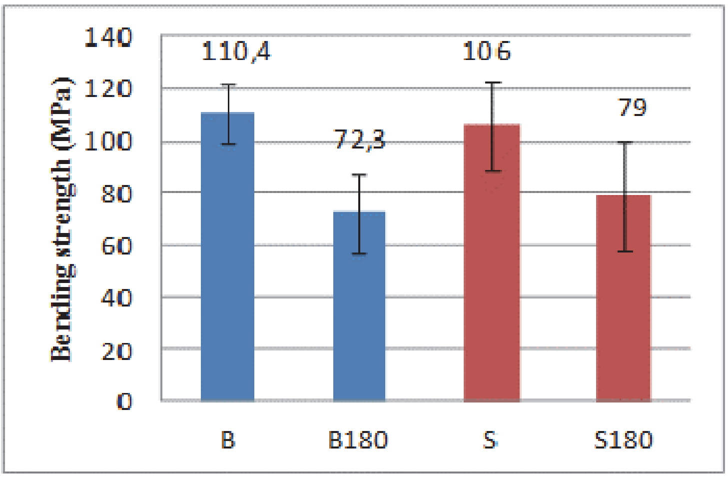

Figure 4. *Bar chart of bending strength in native and false heartwood beech, before and after thermal treatment at 180°C.*

B – beech wood, B_{180} – beech wood thermally treated at 180°C, S – false heartwood beech, S_{180} – false heartwood beech thermally treated at 180°C

Elasticity modulus is almost the same in native beech wood and false heartwood beech. Even though values measured for elasticity modulus under stress in native beech wood are by 6.9% lower than in false heartwood beech, the low significance factor indicates that there is no any drastic difference. Measured values for elasticity modulus are within the values reported in relevant literature (Wagenfuhr 2000, Pejovski 1966).

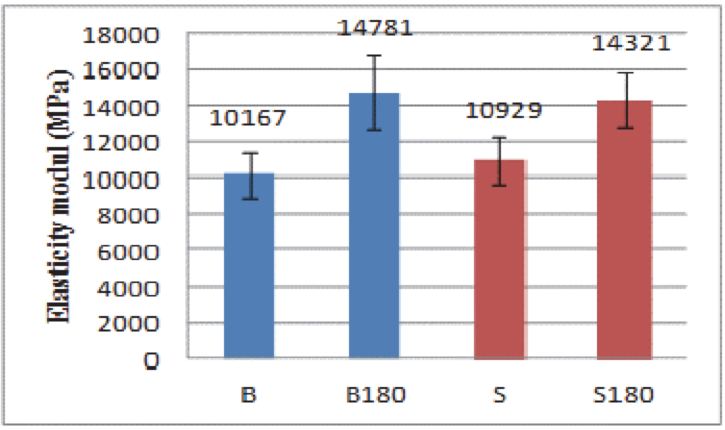

Figure 4. *Bar chart of elasticity modulus under stress in native beech wood and false heartwood beech, before and after thermal treatment at 180°C.*

B – beech wood, B_{180} –beech wood thermally treated at 180°C, S – false heartwood beech, S_{180} –false heartwood beech thermally treated at 180°C

The results show that thermal treatment does not change the wood elasticity.

Thermal treatment at 180°C has a great statistical impact on the increase of elasticity modulus under stress, more with native beech wood, by 31%, and less in the case of false heartwood beech, by 23.7%. Although increment is higher with native beech wood, the mean value of elasticity modulus is higher when comparing its values for native beech wood and false heartwood beech, the difference being only 3.2%, which is of no statistical value. It is known that thermal treatment of wood increases its elasticity modulus (Millertt and Gerhards 1972, Kubojima 2000), but in relevant specialized literature (Thermowood *) it is stated that thermal processing does not change wood elasticity. The data obtained in this study regarding elasticity is appreciably higher than the data in relevant literature.

6. CONCLUSION

Thermal treatment of native beech wood and false heartwood beech causes aesthetic changes, and after thermal treatment at 180°C, there is equalization of the variations in colour and texture. Thermal treatments at higher temperatures only turn wood into dark brown or black.

Native beech wood, compared to false heartwood beech, has lower pressure strength, i.e. false heartwood increases pressure strength. After being thermally treated at 180°C, pressure strength of native beech wood is increased by 5.7%, but after being treated at 230°C, due to the massive decrease in volume, the pressure strength drops by 6.5%. In contrast, after being thermally treated at 180°C and 230°C, pressure strength of false heartwood beech does not change.Regarding bending strength and elasticity modulus under stress, there are no differences between native beech wood and false heartwood beech. Both of these properties change identically after thermal treatment at 180°C of beech wood and false heartwood beech.

It is worth mentioning that there is a drop of bending strength by 34.5% in native beech wood and by 25% in false heartwood beach, which occurs after thermal treatment at 180°C, but the difference between the two is not statistically notable.

Elasticity modulus significantly rises. The increase is more significant in native beech wood, by 31%, than in the case of the false heartwood beech, by 23.7%. Despite the fact that the increase is higher in native beech wood, the difference is not significant.

In the manufacture of sawn beech lumber intended to be processed as thermowood or thermally treated with temperatures above 180°C, during the sawing process it is not recommended to separate beech lumber into native beech wood ("white" beech wood) and false heartwood beech. After being thermally treated, the aesthetic differences are equalized and the changes in pressure strength, bending strength and elasticity modulus under stress, are identical. Beech logs intended to be processed as thermowood can be "sharply" sawn.

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UDC 74.057

STUDY OF BEARING LOADS OF THE CUTTING MECHANISM IN WOODWORKING SHAPER

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ABSTRACT

This study presents the bearing loads of the cutting mechanism in woodworking shaper machine with lower placement of the working shaft. The case of the drive mechanism with the ability to use different pinion gears is examined. Emphasis is placed on the advantages and disadvantages of the machine using a number of belts at different speeds. The study is aimed at improving the reliability and efficiency of wood shaper machine to ensure the accuracy and quality of products.

Key words: Wood shaper, V-belts, ribbed belts, vibration

1. INTRODUCTION

Milling machines are widely available in the woodworking and furniture industry. With them details can be worked right, oblique and profiled. Placement of additional devices allows the user to perform a number of processes such as longitudinal plane milling, making teeth, knots, etc. [1, 6]. Most often wood shapers can be divided in two main types- with bottom location of the working shaft and with up location of the working shaft. Contemporary wood spares should be able to work at different cutting speed. Most often the speed ranges between 30 m/s – 60 m/s [2]. This inevitably is associated with the machinery resources to work at different rotational speed. This creates conditions for variety of loads in the mechanisms that lead to errors during operation. Dynamic effects are constantly changing, which is a premise for permanent shifting loads in the bearings [4, 5]. The high requirements for reducing the level of vibration and noise accompanying the operation of modern woodworking machines requires a deep study of the dynamic processes in them [3]. Wood shapers are characterized by high levels of noise and vibration, which requires a study of their dynamics.

A subject of discussion in this study is a universal wood shaper with bottom location of the working shaft shown in Figure 1. The load on the bearings is researched when using different belt drives to drive the cutting mechanism. The advantages and disadvantages of the machine using a number of belts at different speeds are discussed. The study is aimed at improving the reliability and efficiency of wood shaper machine to ensure the accuracy and quality of products.

Figure 1. *Wood shaper general view*

2. DYNAMIC REACTION

The mechanic-mathematical model is built for the solution of the laid problem shown in Figure 2. It is discreet and includes four discrete masses connected with three massless elastic elements. Reduced mass inertia moments (*kg·m*^{2}) of the cutting mechanism are shown on the figure: J_1 – the mass inertia moment of the electric motor's rotor, J_2 - the mass inertia moment of the belt pulley on the electric motor's shaft, J_3 - the mass inertia moment of the belt pulley on the working shaft , J_4 - the mass inertia moment of the tool.

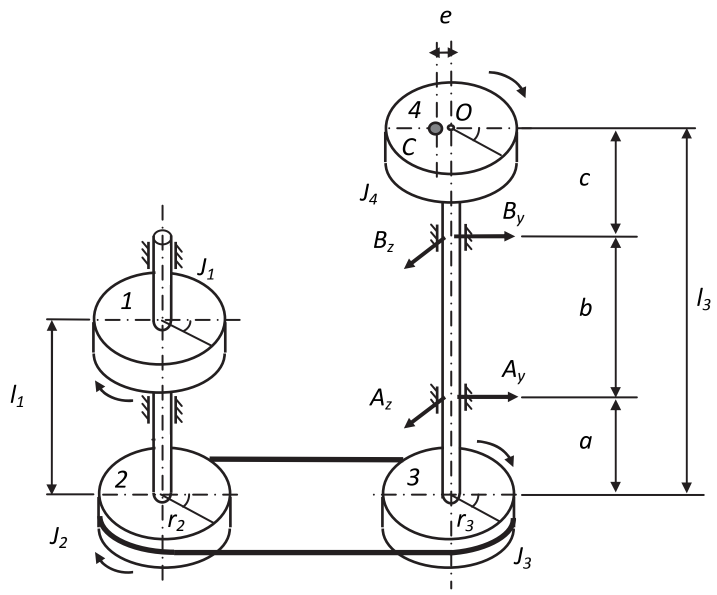

Figure 2. *Dynamic model*

I_1, I_2 - computing length of the electric motor's shaft and spindle (m).
A, B - the supports of the working shaft.
a - distance between belt pulley and support A (m).
b- distance between support A and B (m).
c- distance between support B and tool (m).
R_1, R_2 - radius of the belt pulleys on the electric motors and spindle (m).
έ. - eccentricity between the geometrical axis of the shaft and the displaced axis of rotation (m).

Figure 3 shows the milling tool and the current forces on it.

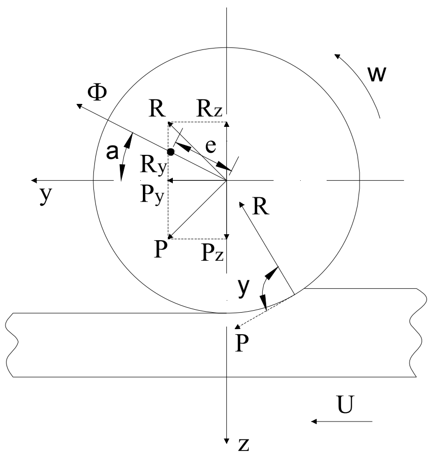

Figure 3. *Cutting Forces*

The average tangential cutting force is calculated by the formula 1.

$$P = \frac{K.b.h.U}{V}, N \tag{1}$$

where K is the specific work of cutting, J/m^3;
b - width of the milling, mm;
h - thickness of the remove layer, mm;
U – feed speed, m/min;
V –cutting speed, m/s.

The average tangential cutting force on the back side of the teeth is calculated by the formula 2.

$$P_з = (a_p - 0{,}8).p.b.\frac{l}{t}, N \tag{2}$$

where a_p is the coefficient of dullness:
p – specific fictitious force on the back side of the teeth, N/m;
b – width of the milling, mm;
l – length of the chip, m;
t – step, m;

The radial milling cutting force is calculated by the formula 3.

$$R = \frac{P_з}{f} - P.\cot g(\delta + \varphi_T), N \tag{3}$$

where $P_з$ is average tangential cutting force on the back side of the teet
f – bent friction;
P – average tangential cutting force, N;
δ – cutting angle, ^{0};
φ – angle of friction, ^{0};
The centrifugal force of the inevitable presence of unbalance of the cutting tool is given by the formula 4.

$$\Phi_1^e = m.\varpi^2.e \tag{4}$$

where m is the mass of the cutting tool, kg;
ώ – angular rate, rad/s
e – distance from the center of gravity of the tool to the axis of rotation, m;
Cutting forces, centrifugal force and the force applied to the pulley decompose the components by the axes x and y.

$$P_x = P\sin\Theta \qquad P_y = P\cos\Theta \tag{5}$$

$$R_x = R\cos\Theta \qquad R_x = R\sin\Theta \tag{6}$$

$$\Phi_x = m.\varpi^2.e\sin\varphi \qquad \Phi_y = m.\varpi^2.e.\cos\varphi \tag{7}$$

Figure 4 shows the cutting forces loading the shaft and the emerging of the respective dynamic reactions from the cutting tool and pulley. They are reduced towards the axis of rotation x.

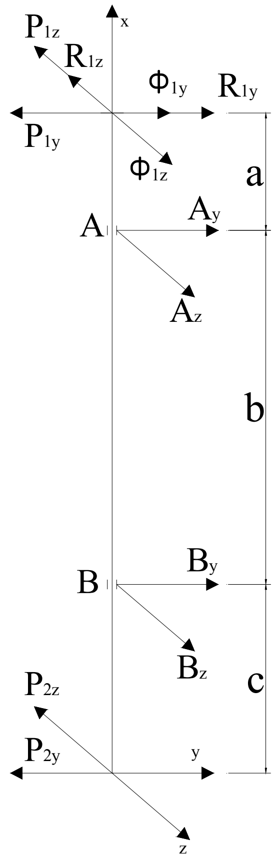

Figure 4. *Dynamic reactions*

3. OPERATION METHOD

To conduct the experimental part a universal wood shaper with bottom location of the working shaft is selected. By using a specialized instrument to measure the vibration Bruel & Kjaer Vibrotest 60 Figure 5 the root-mean-square speed (rms) is measured. [7]. The measurement points are located on the bearing housing of the machine. It significantly responds to the dynamic state.

Figure 5. *Bruel & Kjaer Vibrotest 60*

The exact vibration state measurements need to make in three mutually perpendicular directions (Figure 6.).

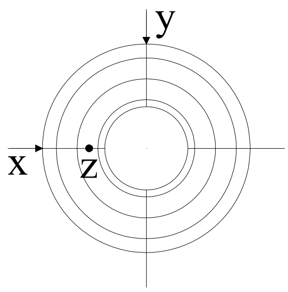

Figure 6. *Measurement points*

A magnet is used to attach the sensor to the bearing housing of the machine (Figure 7.).

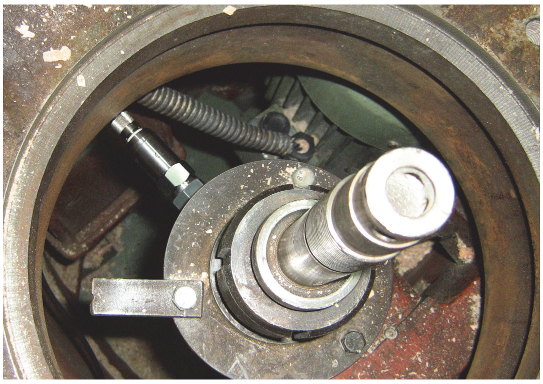

Figure 7. *Attaching sensor*

For the purposes of the study measurements were made with two different types of belts used to drive the cutting mechanism. These are classic V-belt with section Z and ribbed belt - 3PK. Measurements are performed at idle state and during machine operation. The spindle speed is 6000 min^{-1}. A groove cutter with diameter D = 140 mm and width b = 12 mm was used. The thickness of the remove layer is h = 12 mm and the cutting speed is 44 m/s. The treated wood is from pine (pinus negra) with a feed speed U = 10 m/min.

Figure 8 shows the average values of vibration speed (r.m.s). It is measured close to the upper bearing in three mutually perpendicular directions. To drive the cutting mechanism a classical V-belt section Z is used.

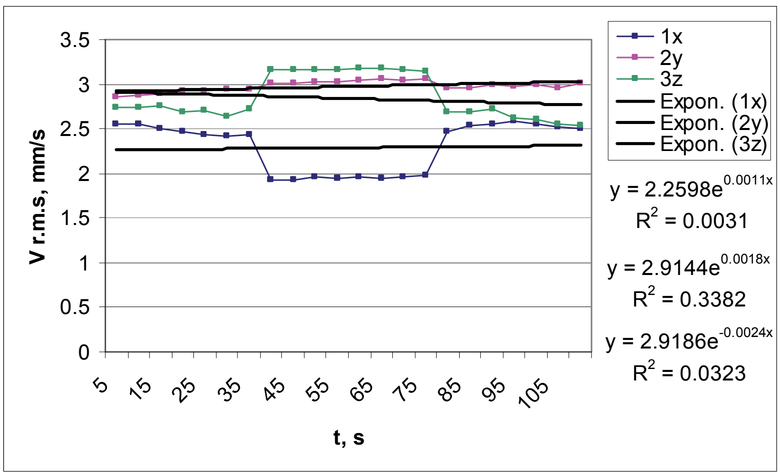

Figure 8. *Average values of vibration speed (r.m.s), upper bearing, belt with section Z.*

Figure 9 shows the average values of vibration speed (r.m.s). It is measured close to the bottom bearing in three mutually perpendicular directions. To drive the cutting mechanism a classical V-belt section Z is used.

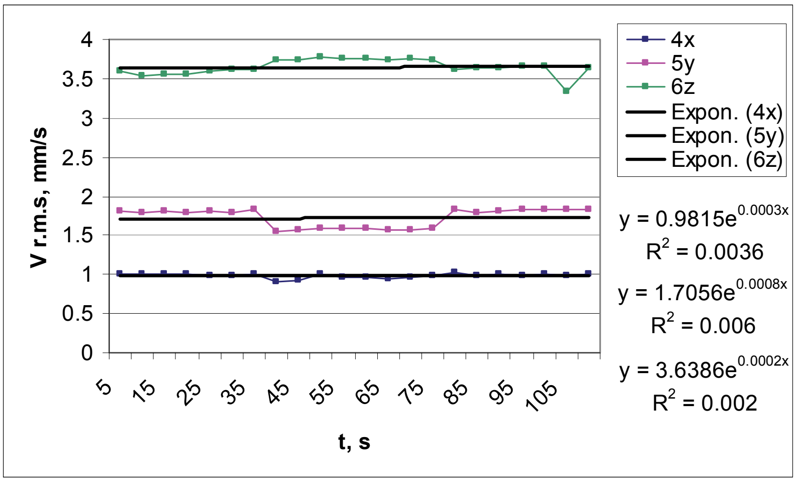

Figure 9. *Average values of vibration speed (r.m.s), bottom bearing, belt with section Z.*

Figure 10 shows the average values of vibration speed (r.m.s). It is measured close to the upper bearing in three mutually perpendicular directions. To drive the cutting mechanism a ribbed belt – 3PK is used.

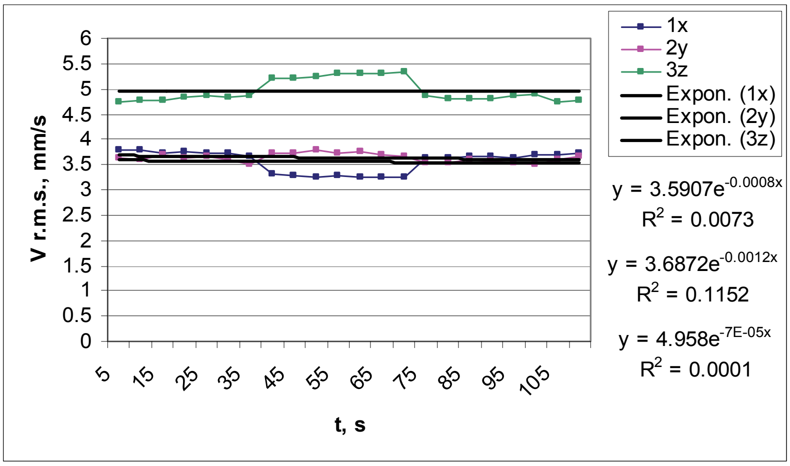

Figure 10. *Average values of vibration speed (r.m.s), upper bearing, ribbed belt 3PK*

Figure 11 shows the average values of vibration speed (r.m.s). It is measured close to the bottom bearing in three mutually perpendicular directions. To drive the cutting mechanism a ribbed belt – 3PK is used.

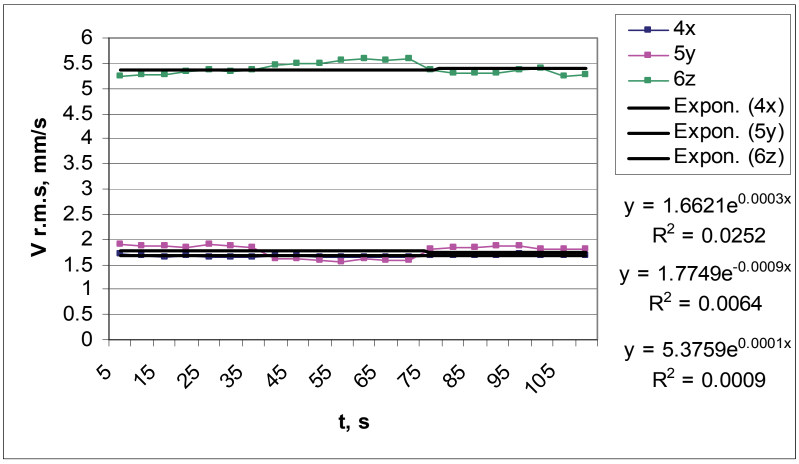

Figure 11. *Average values of vibration speed (r.m.s), bottom bearing, ribbed belt 3PK*

5. CONCLUSION

As a result of research and analysis of the results the following conclusions can be made:

- The graphs illustrate a trend that if we drive the cutting mechanism with a V-belt, the level of measured vibration is lower in all six points.
- Differences in levels at points x and y are not great no matter what type of belt is used.
- The biggest distractions occur in areas 3z and 6z. At some point at work r.m.s. decreases their values and in others the values are increased.

In field 4x, measured near the bottom bearing of the machine, the results illustrate that there are no significant changes in the readings at idle state and during operation.

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INFLUENCE OF THE CUTTER HEADS CONSTRUCTION ON THE NOISE LEVEL PRODUCED BY WOODWORKING MILLING MACHINES

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ABSTRACT

This study investigates the influence of the cutter heads construction on the noise level, produced by woodworking milling machines. For the purpose of our study three cutter heads with different constructive properties but one and the same cutting diameter and teeth number were used. The noise level generated by a milling woodworking machine T1002S equipped with the different cutter heads was measured during idling. Difference in the generated noise level from 2 to 6 dB was registered between the three tested cutter heads.

Key words: noise level, woodworking milling machines, cutter heads

1. INTRODUCTION

For the current evaluation of modern technological equipment, both its technical performance and sound emission levels have to be taken into consideration. Woodworking machines are among of the noisiest working machines. This is mainly due to the mechanical and aerodynamic oscillating processes created by the high rotating speed of their cutting tools (Filipov et al., 1979; Romanchenko, 2010). Ever-increasing quality requirаments of the treated surface is a prereqizite for the production of woodworking machinery with high speed cutting tools. At the same time the speed of the cutting tools is a major factor influencing the level of aerodinamic noise. Aerodinamic noise produced by high speed milling cutters is a serious environmental concern, therefore the assessment of sound emission level is of a great importance in order to assure working environment in compliance with Good Manufacture Practice (GMP). Increased noise levels due to the high rotational speed of the cutting head can be compensated by changes in their structure, linear and angular parameters or by structural changes in the machine itself (Tscheschmedjiev, Dinkov, Brezin, 1988; Svoren, 2011; Kopecký et al., 2012).

Generated noise can be categorized as idling noise and cutting noise, depending on the working process and each one of them has to be assessed and analyzed independently.

Milling machines, thanks to their various applications in furniture and joiner manufacturing are one of the most widespread machines in woodworking and furniture industries. They also belong to the loudest woodworking machinery with A-weighted sound pressure levels $L_{p(A)}$ around 100 dB(A) measured at the work place (HSE, 2007).

The objectives of this study was to trace the relationship and influence of the cutter heads construction on the noise level, generated by woodworking spindle moulder machine during idling.

2. MATHERIALS AND METHODS

The experiments have been carried out using woodworking spindle moulder machine, type T1002S (ZMM "Stomana" GmbH, Bulgaria). The cutting tools used were kindly provided by Metal World – Italy. The cutters differed in their construction but shared equal parameters: cutting diameter D = 125 mm, milling width B = 50 mm, number of teeth z = 4.

The first cutting tool CH 1 (Figure 1a) has a solid construction with solder carbide teeth. The second cutting tool CH 2 (Figure 1b) has an assembled construction and cutting blades parallel to the axis of rotation. The third cutting tool CH 3 (Figure 1c), also contains an assembled construction, but the cutting edges of the teeth are at an angle 30^0 to the axis of rotation.

a b c

Figure 1. *Milling cutting tools used in the experiments*
a) with solid construction b) with an assembled construction and cutting blades parallel to the axis of rotation, c) with an assembled construction and cutting edges of the teeth at an angle 30^0 to the axis of rotation.

In order to monitor the impact of the cutter heads construction on the overall level of noise during operation without cutting (idling), in our first series of experiments the noise level generated by the milling machine with no mounted cutting tools was determined. In our second series of experiments the noise levels during idling were measured, using the milling cutters CH 1, CH 2 and CH 3. All measurements were carried out at a speed of the spindle n = 6 000 min^{-1}.

The experiments were conducted in a free sound field and measurement surface with a shape of right parallelepiped with area S = 31,16 m^2 and one reflecting plane. In accordance with BDS ISO EN 3744:2010 nine measurement points have been determined. The sound pressure level L_p in octave bands with geometric mean frequency from 63 Hz to 16 kHz, in dB and A-weighted sound pressure level in dB(A) have been measured in each of these nine points.

The mean time average sound pressure level in octave bands and A-weighted sound pressure level of the measurement surface are calculated using the following equation:

$$\overline{L_p} = 10\lg\left[\frac{1}{N_M}\sum_{i=1}^{N_M} 10^{0,1 L_{pi(ST)}}\right] - K_1 - K_2 \quad (1)$$

where

$L_{pi(ST)}$ is sound pressure level in octave bands in dB or A-weighted sound pressure level in dB(A), measured at the i^{th} measurement point;

N_M – the number of measurement points;

K_1 – correction coefficient for the background noise, dB;

K_2 – correction coefficient for the test environment, dB.

The sound power level L_w is calculated using the following equation:

$$L_w = \overline{L_p} + 10\lg\frac{S}{S_0} \quad (2)$$

where

$\overline{L_p}$ is time average sound pressure level, dB;

S – total area of the measurement surface, m^2;

$S_0 = 1$ m^2.

The sound pressure level of the working place was measured at an additional measurement point (point ten) placed at a distance of 1 m from the machine at a 1,5 m height from the floor.

The measurements were performed using precise impulse sound level meter (RFT – Germany) with built in 1/1 octave band filters and mean geometric frequencies as follow: 31,5, 63, 125, 250, 500, 1 000, 2 000, 4 000, 8 000, 16 000, 31 500 Hz. This sound level meter measures both linear sound pressure levels and sound levels, corrected according to the standard frequency characteristics A, B, C and D with a frequency range from 20 to 20 000 Hz. The measurements were done at a time constant "fast" (F). The entire measurement tract has been calibrated before the initiation of the experiments, using a standard sound source Pistonfon PF 101 with a constant sound pressure level equal to 117,1 dB on $p_0 = 2.10^{-5}$ $N.m^{-2}$ at a frequency f = 180 Hz.

The requirements given in EN ISO 3744:2010 and BDS ISO 7960:2007 were strictly followed throughout the experiments.

3. RESULTS AND DISCUSSION

Measured differences in the sound power level L_w have been used as a basis of comparison between the sound generated from the tested spindle moulder machine, equipped with three different cutting tools. Figure 2 gives the distribution of the sound power level in octave bands and A-weighted sound power level in dB measured during idling with and without the tested cutting tools CH 1, CH 2 and CH 3. The results showed similar distribution of the sound power level, measured during idling without tools or with cutters CH 2 and CH 3.

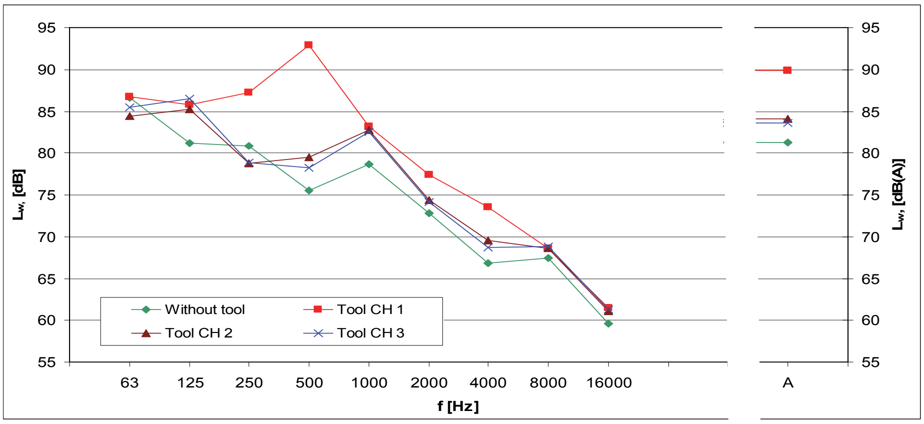

Figure 2. *Sound power level in octave bands and A-weighted sound power level in dB during idling and rotating speed of the spindle 6 000 min^{-1}*

Along the entire tested frequency range cutting tool CH 1 showed the highest sound power level, with a peak value of 92,9 dB in octave band with mean geometric frequency of 500 Hz.

For the cutting tools CH 2 and CH 3 the highest values of the sound power level were measured in the low and mid frequency range. In the low frequency range (octave band with mean geometric frequency of 125 Hz) the sound power level was equal to 85,3 dB and 86,5 dB for CH 2 and CH 3, respectively. In the mid frequency range (octave band with mean geometric frequency of 1 000 Hz) the sound power level was equal to 82,7 dB for CH 2 and 82,5 dB for CH 3.

When comparing the A-weighted sound power level for the three tested cutting tools, CH 1 had the highest value – 89,9 dB(A) and CH 3 had the lowest – 83,6 dB(A). For the CH 2 the A-weighted sound power level was measured to be 84,1 dB(A).

The noise level emitted by the CH 2 and CH 3 cutters was approximately 5,8 – 6,3 dB(A) lower when compared to the noise level emitted by the CH 1 cutter. This could be explained by the "enveloped" shape of the cutting bodies of tools CH 2 and CH 3. Due to constructive properties of CH 1 cutter there are sort of "pockets" formed in the cutting body which are responsible for twisting of the air flow and as a consequence, increase the aerodynamic noise.

Lower noise level, by 0,5 dB(A), emitted by CH 3 in comparison to CH 2 are due to the cutting edges of the tools inclined toward the axes of rotation. Thus the air flow meets the cutting edge gradually which allows the compressed air to move along the cutting edge.

In the current study the changes in the noise level due to different constructions of the cutting tools, were measured also at the working place. The measurements were performed during idling, with and without cutting tools and the rotation speed of the spindle was n=6 000 min^{-1}. The changes in the A-weighted sound pressure level are shown in Table 1.

Table 1. *A-weighted sound pressure level L_p measured at the working place during idling, with and without cutting tools*

Without cutting tool [dB(A)]	Cutting tool CH 1 [dB(A)]	Cutting tool CH 2 [dB(A)]	Cutting tool CH 3 [dB(A)]
65,5	74,4	68,6	68,6

From the data given in Table 1 it is evident that during idling with mounted cutting tool CH 1 the sound pressure level increased by 8,9 dB(A), while with mounted cutting tools CH 2 and CH 3 it increased by 3,1 dB(A).

4. CONCLUSION

The results of the current study give us information about the range in which the sound power level, generated by the woodworking spindle moulder machine during idling changes, depending on the construction of the cutting tools used.

On the basis of the performed experiments and the results obtained after comparing the sound power level produced by three milling cutting tools with different construction, could be concluded that the design of the cutting tools influence the generated total sound power level, measured during idling. When the machine operates without mounted tools, the measured sound power level was 81,3 dB(A) which is below the sanitary standard of 85 dB(A). When the machine operates with mounted cutting tools the measured sound power level increased as follows: with a cutter CH 1 – by 8,6 dB(A), with a cutter CH 2 – by 2,8 dB(A) and with a cutter CH 3 – by 2,3 dB(A).

The sound pressure level values measured at the working place are below the sanitary standard of 85 dB(A). The results of our study showed that among the tested milling cutting tools, CH 2 and CH 3 are responsible for less noise production than CH 1 which is the noisiest.

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QUALITY IS THE KEY TO COMPETITIVENESS STANDARDS ARE THE BASIS FOR IMPROVEMENT AND QUALITY ASSURANCE

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ABSTRACT

Quality movement in the world is part of the engagement in global and European business, and the world in the new century is characterized by globalization, liberalization and technological development. Globalization is a process of economic, social, cultural and political action that goes beyond the boundaries of nation states.

Repeatedly, it is emphasized that quality becomes a fundamental way of running any business, anywhere on earth.

Macedonia should create an environment for the successful integration of our economy into European and international processes, and it is only possible with the harmonization of national legislation with the EU, and the acceptance of European standards as Macedonian standards. It should be the result of joint efforts of state bodies, the economy, the academic community, experts and various associations, in order to ensure the development of the country's economy and standard of living.

It is recommended to the producers to apply the harmonized standards, even if they are not obligatory. Their use is the basic presumption for conformity of the product with the relevant directive.

Key words : directive, quality harmonization standards, conformity

1. INTRODUCTION

The existing regulations of the European Union (EU) guarantee the free movement of goods and a high level of customer protection, using the basic principle that only safe products can be placed on the market. The technological barriers founded on the different requirements of the products and the different procedures for the conformity assessment of a suitable product, are exceeded by harmonization of the quality requirement and the mutual recognition of the quality assessment established by the member states.

The instruments for ensuring the free movement of goods within the EU are: the principal of mutual recognition of legally placed products and technical conformity of legislation and mechanisms to prevent the creation of barriers in trade. Technical harmonization aims to put aside the regulations that create barriers in trade, so that trade conforms to national technical legislation, recognising the public interest of every state, such as: health care and safeguarding and protecting the environment.

The principal of mutual recognition: the product that is legally placed on the market in one member state should be allowed placement on the markets of all other member states.

2. QUALITY INFRASTURCTURE

To persist in the global market, it is necessary on the internal (national) market to have established a quality infrastructure which consists of the activities of standardization, accreditation, conformity assessment, and metrology and market surveillance.

The standardization principles are the basis of the European quality infrastructure. Sometimes we do not notice the influence of standards on our everyday life, but the impact of standards in the economy can be far-reaching.

Figure 1, shows the basic connections and the central role of the standardization within the quality infrastructure.

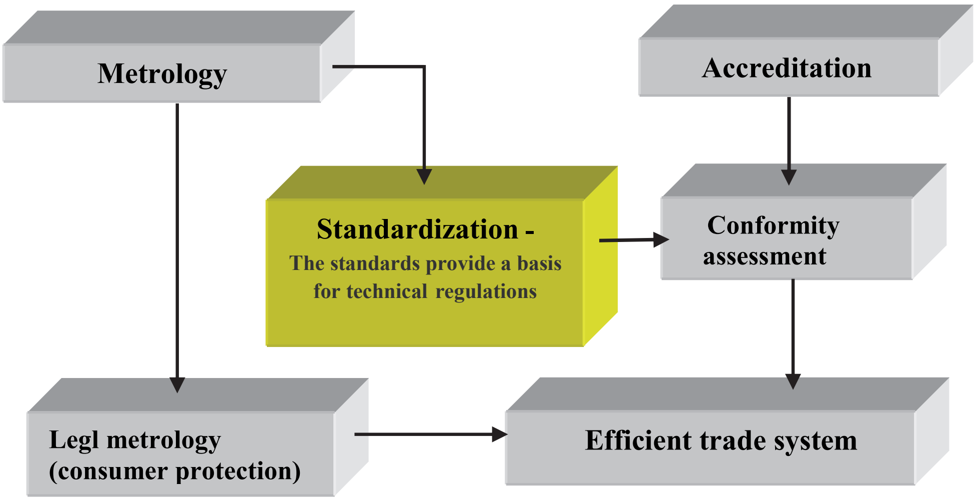

Figure 1. *Link between metrology, standardization and conformity assessment*

These institutions allow sustainable development that can lead to full participation in international trade and can fulfil the technical requirements of the multilateral trade system.
A priority of every government in every developing country is establishing and maintaining a basic infrastructure so that it can guarantee the safety, health and welfare of all its citizens – an adequate and safe provision of food, drinking water, healthcare and education availability, social safety, transportation, communication systems, etc. Only when all of this is set in place, even at its elementary level, the need of establishing an **efficient trade system** becomes the most important.

3. THE PROCESS OF HARMONIZATION OF THE NATIONAL TECHNICAL LEGISLATION

The process of harmonizing national technical legislation with European legislation is shown in figure 2 and is based on the transposition of the European Directives/Regulations of the New approach of technical conformity and the Global approach for conformity assessment.

The directives represent the European legislation that cannot be directly applied; member states have to transpose their national legislation. Unlike the directives, the regulations are directly applicable after its adoption by all member states.

The directives/regulations, based on the basic principle of the New and the Global approach, cover a large group of products and types of risk and determine only the basic requirements that the products have to fulfil.

3.1 Construction products Directive 89/106 EEC (*CPD)*

The European Union has prepared 30 directives and regulations of the New approach for a different array of products including Directive of Construction Products 89/106 EEC, CPD, which regulates the conditions for the release of construction products on the market.

Products can be placed on the market only if they are fit for their intended use; that means, works in which the products are incorporated should fulfil the essential requirements. Product groups affected by the CPD are: aggregates, acoustics, cement and building limes, chimneys, concrete and related products, doors, windows, shutters, building hardware and curtain walling, durability of wood and derived materials, fire detection and fire alarm systems, glass used in building, masonry, gypsum, geosynthetics, road equipment, road materials, wood-based panels.

The European parliament and the Council on 9 March 2011 adopted REGULATION No 305/2011-CPR, laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106 EEC-CPD. The Regulative 305/2011 shall apply from 1 July 2013. Construction products which have been placed on the market in accordance with Council Directive 89/106 EEC-CPD before 1 July 2013 shall be deemed to comply with Regulation.

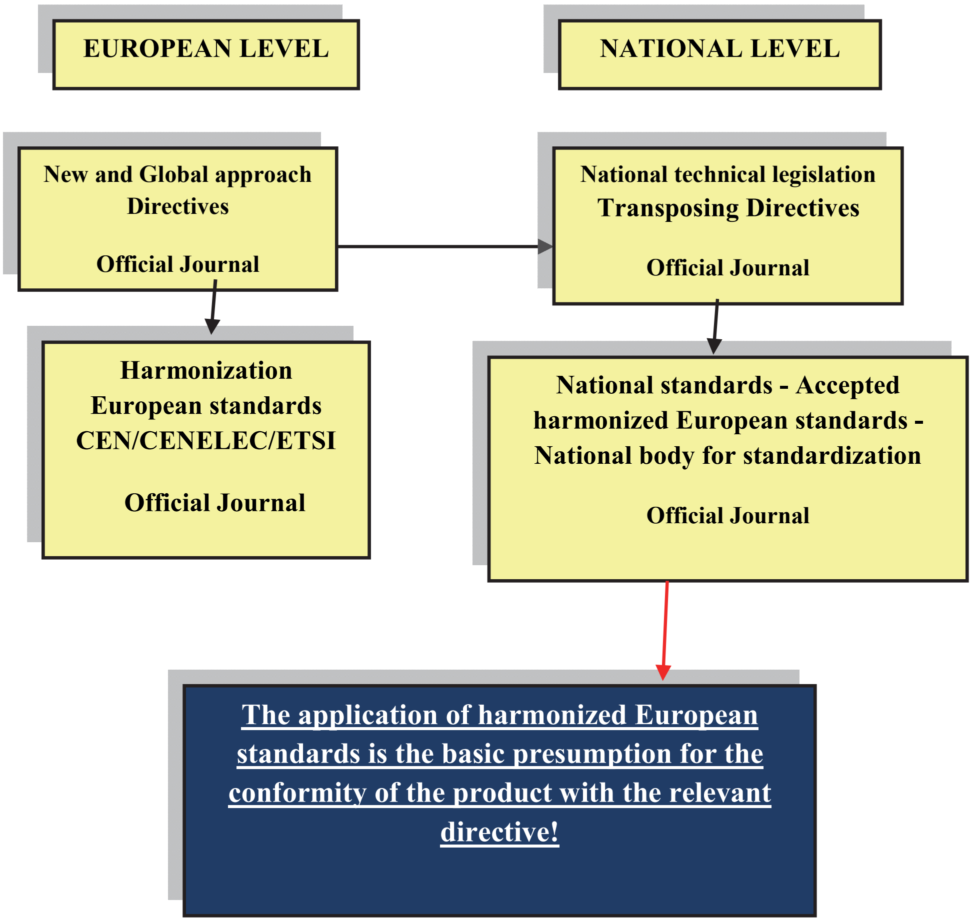

Figure 2. *Presentation of the process of technical harmonization*

3.2 Harmonized standards

Harmonized standards (hEN) are European standards established by the European standardization organizations (ESO) under the mandate of the European Commission and/or European Free Trade Association (EFTA). All stakeholders are involved in the process of developing harmonized standards through European standardization organizations. ESO shall ensure that the various categories of stakeholders are in all instances represented in a fair and equitable manner. Harmonized standards shall provide the methods and the criteria for assessing the performance of construction products in relation to their essential characteristics.

The Commission shall publish in the Official Journal of the European Union the list of references of harmonized standards which are in conformity with the relevant mandates.

The following shall be indicated for each harmonized standard in the list:

(a) references of superseded harmonized technical specifications, if any;

(b) date of the beginning of the coexistence period;

(c) date of the end of the coexistence period.

The Harmonized standards support the essential requirements of the "New Approach" Directive / Regulation.

The products, made in conformity with the harmonized standards have a presumption of conformity to the essential requirements of certain directives.

In the area of CPD, around 2000 standards are in preparation, while about 600 standards are fully harmonized. Standards are classified according to the groups of products for which they are intended. The list of harmonized standards can be found on the European Commission web site.

Construction works as a whole and in their separate parts must be fit for their intended use, particularly taking into account the health and safety of persons involved throughout the life cycle of the works. Subject to normal maintenance, construction works must satisfy these basic requirements for construction works for an economically reasonable working life:

1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and the environment
4. Safety and accessibility in use
5. Protection against noise
6. Energy economy and heat retention
7. Sustainable use of natural resources

The differences in the essential requirements between the Directive and the Regulation are in the seventh condition, which wasn't included in the Directive.

The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and, in particular, ensure the following:
(a) reuse or recyclability of the construction works, their materials and parts after demolition;
(b) durability of the construction works;
(c) use of environmentally compatible raw and secondary materials in the construction works

3.3. Harmonized standards in the area of wood, wood products and furniture

Harmonized standards in the area of wood and wood products are assembled in more areas and covered within the competence of several European committees. A review of the European technical committees, with examples of harmonized standards and a short description of the standard area, is given in **Annex I** of this thesis.

What is common for every example of harmonized standards in **Annex I** is that all of them are about the basic requirements that should be satisfied by the products; that is, the characteristics, the conformity assessment and the labeling of the products. The harmonized standards in this area apply to several directives, which are also given in the table of **Annex I.**

Moreover, it is important to mention that, besides the above mentioned harmonized standards, there are other types of standards:

Standard for terminology - is a standard that applies to the terms, usually accompanied by their definitions and sometimes explanatory notes, drawings, examples, etc.
(MKC EN 45020:2011, definition 5.2)

- **MKC EN 844-2:2010** Round and sawn timber – Terminology – Part 2: General terms relating to round timber,
- **MKC EN 300:2010** Oriented Strand Boards (OSB) – Definitions, classification and specifications;

Standard for testing – is a standard that concerns testing methods, sometimes supplemented by other provisions that regard testing, for example: taking samples, use of statistical methods and the test schedule.
(MKC EN 45020:2011, definition 5.3)

- **MKC EN 1335-3:2010** Office furniture – Office work chair – Part 3: Test method,
- **MKC EN 12211:2010** Doors and windows – Resistance to wind load– Test method,
- **MKC EN 1027:2010** Doors and windows – Watertightness – Test method.

Product standard – is a standard that specifies the requirement that the product or the group of products should meet so that their conformity is ensured.

NOTICE 1: Except for the conformity requirements, the product standard can directly or through reference, point upon terminology, sample taking, testing, packing, marking and sometimes processing requirements.
NOTICE 2: A product standard can be complete or incomplete, depending on whether it determines all or just a part of the necessary requirements. In that sense, we can differentiate between standards for measure, materials and technical standards for delivery.
(MKC EN 45020:2011, definition 5.4)

Example for product standard:

- **MKC EN 1313-2:2010** Round and sawn timber – Permitted deviations and preferred sizes – Part 2: Hardwood sawn timber
- **MKC EN 13761:2010** Office furniture – Visitors chairs
- **MKC EN 1522:2011** Windows, doors, shutters and blinds – Bullet resistance – Requirements and classification.

3.4. Why should the manufacturers use the harmonized standards if their application is voluntary?

The use of the harmonized standards, and referring to them, is the easiest and simplest method to guarantee product conformity with the basic requests of the relevant directive. It is recommended to producers to apply the harmonized standards, although they are not mandatory.

So, the producer can choose whether to apply the harmonized standards or not. If the producer decides not to use the harmonized standards, he is obliged to prove that his product conforms to the essential requirements of the relevant directive. For example: he can use basic (non-harmonized) European standards, special national standards or other technical specifications. The presentation of the presumption of conformity is given in Figure 3.

If the producer uses just part of the harmonized standard, or if the applicable harmonized standard does not cover all the essential requirements, the producer must guarantee conformity to all of the essential requirements in some other way. In those cases, calling strictly upon the harmonized standard does not ensure the presumption of conformity.

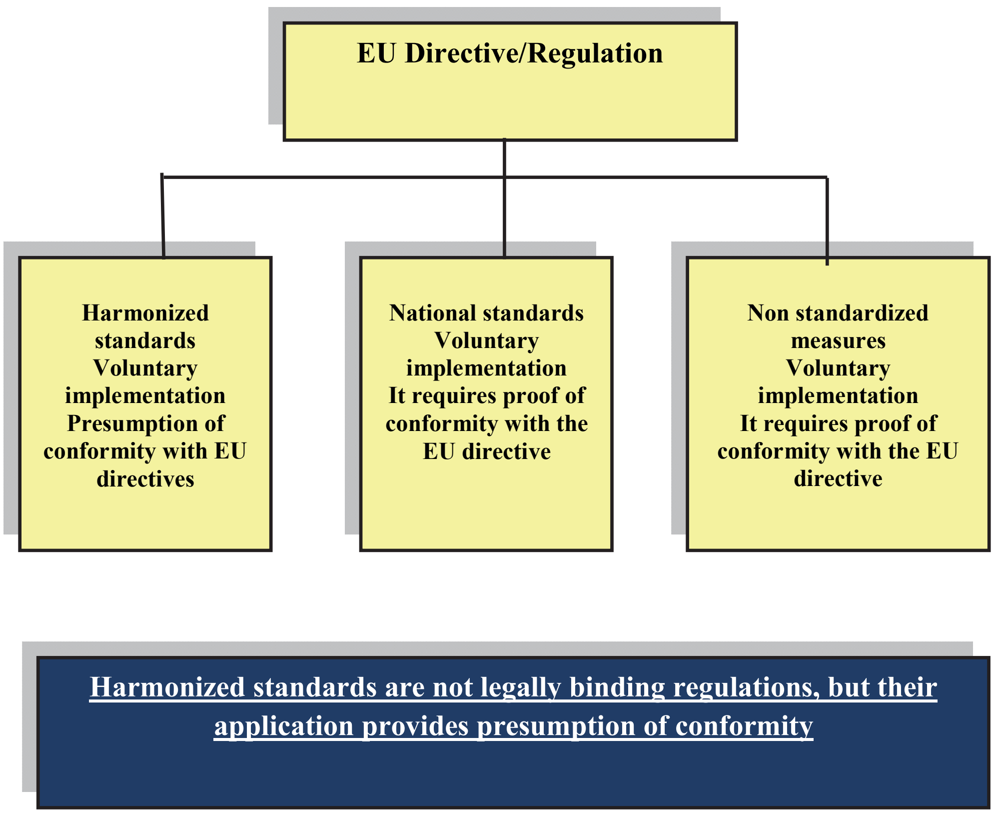

Figure 3. *Presentation of presumption of conformity*

If the producer decides to use a harmonized standard, he must give proof of the conformity of his product to the harmonized standard - Conformity Declaration. Making this declaration, the producer takes the responsibility for the conformity of the building product for intended use. But, according the Regulation 305/2011, this declaration is called "Declaration of performance" and its content is stipulated within the Regulation. According to the declaration, the producer prepares technical documentation in which all relevant elements that refer to the necessary system of assessment and confirmation of the sustainability of the performance are described.

Furthermore, according to the new Regulation 305/2011, if the construction product is not included at all or not included entirely within the harmonized standard, a "European Assessment Document" is issued. This document is prepared and issued by the Technical Assessment Body.

On those products for which a declaration is prepared the producer affixes a "CE" marking.
By affixing or having affixed CE marking, manufacturers indicate that they take responsibility for the conformity of the construction product with the declared performance. The "CE" mark shall be affixed before the product is put on the market.

Depending on the criticality of the product according to the safety requirements, the conformity assessment procedures for the "CE" mark differ between the directives, and for some products even within the frames of the directive itself.

Every Directive includes details of the required modules or ways to the CE mark. They vary from a simple declaration of conformity of the product to sample taking and testing of the product by an independent body (laboratory/notification body) for conformity assessment.

When the product is subjected to several directives of the New approach, the marking of the product supposes that the product meets the provisions of all relevant directives. Basic principles, such as the form and dimensions of the "CE" mark, are prescribed within the EU Regulation No.765/2008.

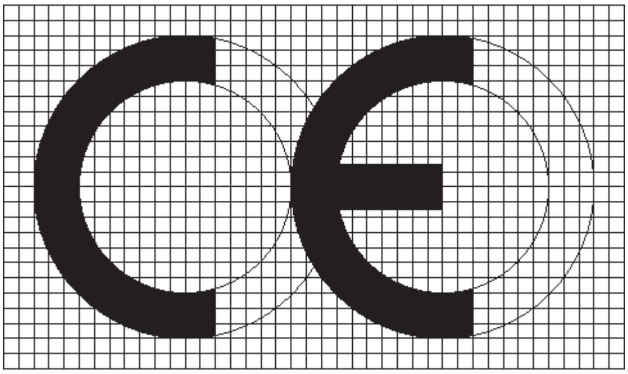

Figure 4. *Presentation of "CE" mark*

4. APLICABLE NATIONAL TECHNICAL REGULATIVE FOR CONSTRUCTION PRODUCTS

On the April 9, 2001 in Luxemburg, The Republic of Macedonia undersigned the Treaty for Stabilization and Association with the European Community and its member states. The area of free movement of goods is covered by articles 68 and 73 stated in chapter 6 of the Treaty for Stabilization and Association, which stipulates "Conformity of the legislation and law enforcement".
Article 68 concerns the fact that the Republic of Macedonia persists to ensure compatibility of its laws with the ones of the European Community.

According to article 73 of the Treaty, the Republic of Macedonia undertakes the following necessary measures:
- Accelerating the development of standardization as one of the pilars of the quality infrastructure;
- Encuraging participation in the work of the European standardization bodies (CEN, CENELEC, ETSI, EA, WELMEC, EUROMED, etc.);
- Establishing the European protocol for conformity assessment anywhere it is needed;
- Encouraging the use of the technical regulations of the Community and the European procedures for standards, testing and conformity assessment.

The Construction Products Directive (CPD) is transposed in Macedonia within the LAW ON CONSTRUCTION PRODUCTS (Official Gazette of the Republic of Macedonia No.39/2006).With this Law, the conditions for issuing construction products on the market and attesting procedures are regulated, as are other questions relevant for construction products.

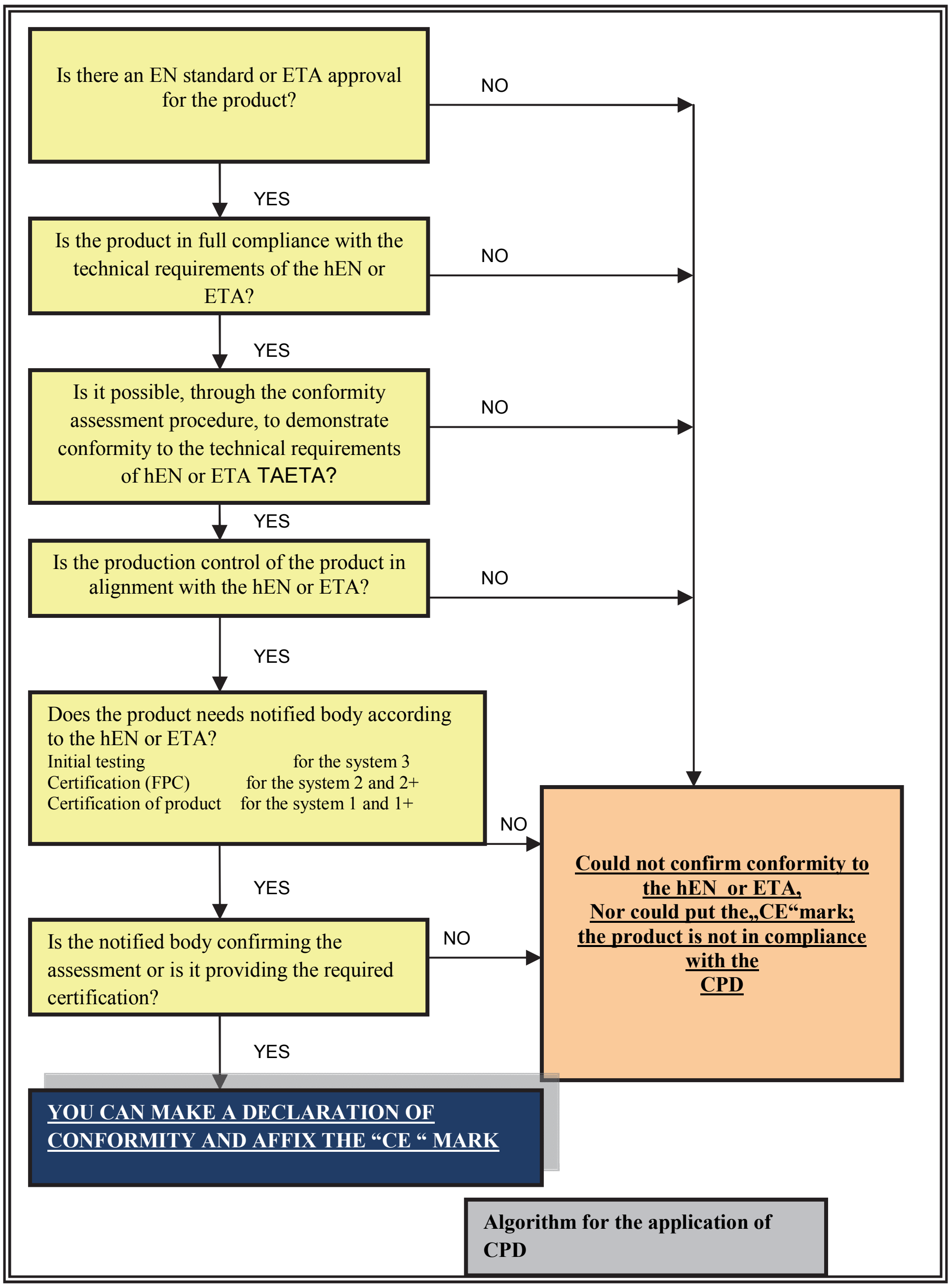

Figure 5. *Presentation of how to make a declaration of conformity and affix the "CE" mark*

In 2006 the following secondary acts were issued:

- Rulebook for the essential requirements for construction objects ("Official Gazette of the Republic of Macedonia" No.74/06);
- Rulebook for the attesting method, attesting procedures, construction products marking, and the content of the conformity documents ("Official Gazette of the Republic of Macedonia" No.74/06);
- Rulebook for the essential requirements for fire safety of construction products ("Official Gazette of the Republic of Macedonia" No.94/09).

5. CONCLUSION

Standards are amongst the most important tools used by the managing structures within the organizations.

It is important to note that the producers with an established quality management system will not automatically assure the presumption that their product conforms to the "CE" marking. The relevant directives of the New approach will stipulate correctly and entirely the direction for the conformity assessment.

The standards are also a tool when we shape, examine and certify the product; and, not only the product, but also technological or production systems or service systems. The meaning of standardization grows with the growth of the global market and the increase in choice of products and services.

The movement for quality in the world is a part of the efforts of global and European business to adjust to the changes in the global market, always noting that quality stays a fundamental way of making every business everywhere in the world.

"Quality can not be a goal, but a means for achieving the goal – and that is the quality of life"
Warning by Ralph Nader

ANEX I Review of the European technical committees, with examples of harmonized standards, Directives and a short description of the standard area

European technical committee (TC)	Title of TC	Directive	Example of harmonized standards	Scope
1	2	3	4	5
CEN TC 033	**Doors, windows, shutters, building hardware and curtain walling**	**Directive 89/106/EEC Construction products**	MKC EN 1125, MKC EN 1154, MKC EN 1155, MKC EN 1935, MKC EN 12209	standards for building hardware – emergency exit devices, panic exit devices, controlled door closing devices, door coordinator devices, locks and latches, single-axis hinges
			MKC EN 13241-1, MKC EN 12635, MKC EN 12978	standards for industrial, commercial and garage doors and gates
			MKC EN 13561	external blinds
			MKC EN 13659	shutters
			MKC EN 14351-1	windows and doors
CEN TC 112	**Wood-based panels**	**Directive 89/106/EEC Construction products**	MKC EN 13986	wood based panels for use in construction
CEN TC 124	**Timber structures**	**Directive 89/106/EEC Construction products**	MKC EN 14080, MKC EN 14081-1, MKC EN 14250, MKC EN 14372	standards for timber structures-glued laminated timber, strength graded, product requirements
CEN TC 175	**Round and sawn timber**	**Directive 89/106/EEC Construction products**	MKC EN 14342, MKC EN 14915	wood flooring, solid wood panelling and cladding
CEN TC 207	**Furniture**	**Directive 2001/95/EC General product safety**	MKC EN 1129-1, MKC EN 1129-2 MKC EN 1130-1, MKC EN 1130-2	standards for furniture – foldaway beds, cribs and cradles for domestic use
CEN TC 142	**Woodworking machine- Safety**	**Directive 2006/42 EC Machinery**	MKC EN 1218, MKC EN 1870	tenoning machines, circular saw benches

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POSSIBILITIES FOR IMPROVEMENT OF THE CONTROL OF THE TECHNICAL STATE AND DETERMINATION OF THE SERVICEABILITY OF CARVED VENEER MACHINES

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ABSTRACT

Some problems of improvement of vibration control methods and passing serviceability of a carved veneer machine are discussed in this paper. Criterion for estimation of the technical state and determination of passing serviceability is formed on the base of the investigation of torsional vibrations by using an original dynamical model. Special features in the construction and peculiarities of the work regimes in exploitation of these machines are modeled. Investigations indicate that regular diagnostics increase the reliability and the effectiveness and decrease the expenses of the repair and service. It guarantees the precision and the quality of the production with carved veneer machines at the same time.

Key words: vibration control, carved veneer machines

1. INTRODUCTION

The right control on the technical state and the precise determination of the passing serviceability of carved veneer machines are important for increase of the effectiveness, cheapness and precision of the production. On the one hand, the right diagnostics leads to minimum expenditure for repair and service. On the other hand it helps to find some diversions in the parameters of the machine which guarantees the precision and quality of the veneer production. Consequently, expenses from spoilage and unused production go down. Moreover, the right diagnostics decreases the level of the noise and vibrations connected with the manufacture. It refers special requirements to the level of noise and vibrations. The analysis of the data of special requirements of the diagnostics can be used as a basis in reconstruction and modernization of machines because it indicates their friar elements.

The fast development of current means for computer modeling and analysis of complicated dynamical systems gives new possibilities for application of the technical control (Amirouche, 2006; Coutinho, 2001; Vukov, 1992). It mainly refers to its fastest-developed branch – vibrocontrol. Its main advantages are connected with the expenditure of time, labor and money for creation of one or more initial material models which are investigated in different work regimes and which can be changed. Complicated and expensive devices which are used for registration and analysis of vibrosignals in the machine are not necessary (Genkin and Sokolova, 1987; Minchev and Grigorov, 1998). That indicates the advantages of the computer modeling – it allows to create investigate and analyze a lot of variations of the construction including different conditions of its optimization. Therefore, it is possible to investigate different work regimes, even those, which are extremely difficult for investigation in different conditions – for example, in breakdown regimes, starting, stopping regimes and etc. If the machine is more complicated and expensive, as carved veneer machines, its advantages become more and more.

There are a lot of difficulties in this kind of diagnostics of carved veneer machines, except for advantages. The work of these machines is usually connected with the extremely high level of vibrations and noise. Some changeable factory as work regimes of a machine, characteristics of processing wood, its negative features (cracks, some harm caused by insects and etc.) have influence on vibrosignals (Genchev and Obreshkov, 1987). As a result, the measured vibrosignal becomes extremely complicated and difficult for analyzing. In this signal, except for the useful information about the machine state, there is also a lot of "noise" which is connected with these factors. Therefore, it is necessary to investigate dynamical processes and vibrations of machines in advance according to their special features which allow evaluating their technical state.

Cases when intensive vibrations with rather high amplitudes appear in definite work regimes of the machine are very interesting for practice. Extra dynamical loads in the whole construction forms in these regimes and it leads to breaking of its serviceability. The machine diagnostic of state points, there are not fault. All that requires detailed analysis of the vibration behavior of the system. The results show that the breaking of the serviceability in these regimes is connected with work nearby resonant zones. These zones depend on the construction and the peculiarities in the machines' work. That research of the construction and finding of the known regimes in advance would give a possibility to take actions for their movement out of work regimes. It could guarantee the normal serviceability of the machine.

Some possibilities for improvement of methods for diagnostics and determination of the passing serviceability of carved veneer machines are offered in this paper. Therefore some modern ways and means for computer modeling and analysis of complicated dynamical systems are used in order to this aim. Its application can lead to increase of effectiveness, economics and reliability of the production of the carved veneer machines.

This paper is a continuation of previous papers written on the same theme (Vukov, 2001; Vukov, Vlasev, Todorov and Marinov, 2003; Vukov, 2005; Vukov, 2008), which investigate dynamical processes and vibrations in horizontal carved veneer machines made on the base of an original dynamical model.

2. DYNAMIC MODEL

Figure 1 shows a view of a carved veneer machine.

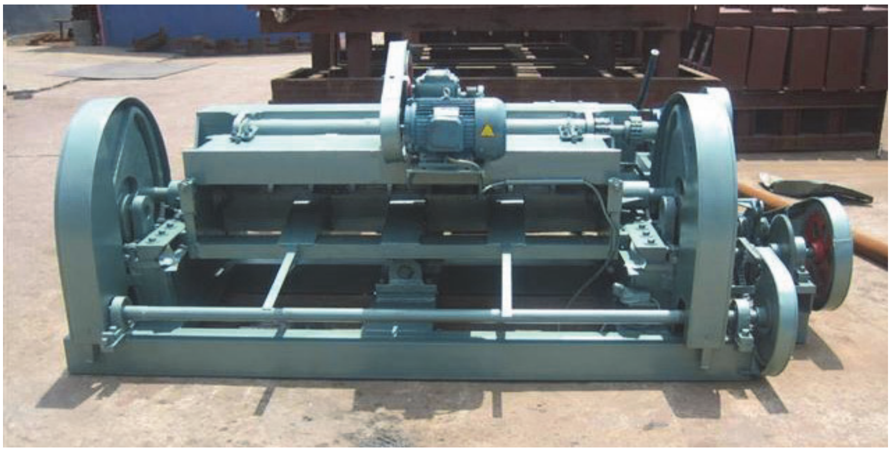

Figure 1. *Carved veneer machine*

The scheme of the driving mechanisms of a carved veneer machine (Filipov, 1977 and Obreshkov, 1997 is shown in Figure 2. The scheme includes: *1* – electric motor, *2, 4* – belt pulleys, *3* – belts, *5, 8* –shafts, *6, 7* – gear wheels, *9* – flywheel, *10* – connecting rods, *11* – tool slide, *12* – guides.

The built dynamical model for investigations of the torsional vibrations of the driving mechanisms of a carved veneer machine is shown in Figure 3. The exit shaft of the electric motor is accepted as a refer axis in the formation of the dynamical model. The reduction of all parameters of the dynamical model is made relating with this refer axis. The dynamical model includes four discrete masses, connected by three mass less elastic shafts.

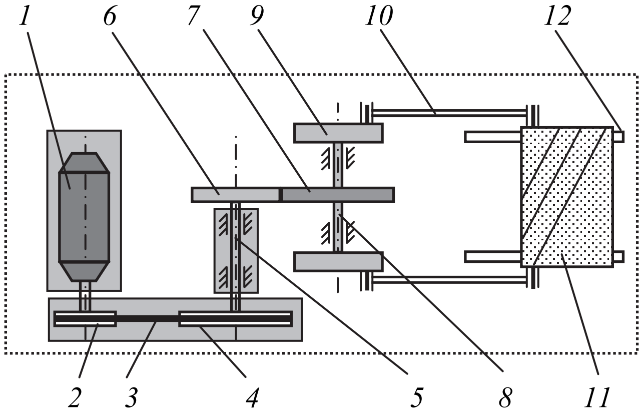

Figure 2. *Schematic sketch of a veneer machine*

The mass parameters of the real system are designed by four masses, and the reduced mass inertia moment is defined for each of them. The reduced mass inertia moments give:
– I_I – the mass inertia moments of the electric motor and the belt pulley on its shaft;
– I_{II} – the mass inertia moment of the belt pulley *4*;
– I_{III} – the mass inertia moment of the gear wheels *6* and *7*;
– I_{IV} – the mass inertia moment of the flywheels *9*, connecting rods *10* and tool slide *11*.
The stiffness is
– c_I – stiffness of the belt gearing;
– c_{II} – stiffness of the shaft *5*;
– c_{III} – stiffness of the shaft *8*.

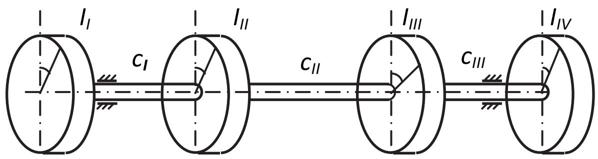

Figure 3. *Dynamical model*

The differential equations, which describe the torsional vibrations of the mechanism, are obtained by aid of the Lagrange's equations. They are:

$$\begin{vmatrix} I_I & 0 & 0 & 0 \\ 0 & I_{II} & 0 & 0 \\ 0 & 0 & I_{III} & 0 \\ 0 & 0 & 0 & I_{IV} \end{vmatrix} \begin{vmatrix} \ddot{\varphi}_1 \\ \ddot{\varphi}_2 \\ \ddot{\varphi}_3 \\ \ddot{\varphi}_4 \end{vmatrix} + \begin{vmatrix} c_I & -c_I & 0 & 0 \\ -c_I & (c_I + c_{II}) & -c_{II} & 0 \\ 0 & -c_{II} & (c_{II} + c_{III}*) & -c_{III}* \\ 0 & 0 & -c_{III}* & c_{III}* \end{vmatrix} \begin{vmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \end{vmatrix} = \begin{vmatrix} M \\ 0 \\ -M_0 \sin \omega_1 t \\ M_0 \sin \omega_1 t - M \end{vmatrix}, \quad (1)$$

where φ_1, φ_2, φ_3, φ_4 are the angles of rotation of the rotors,
M_0 – amplitude of the variable torsional moment,
M – rotation moment,
ω_1 – frequency of rotation of flywheels.

3. MAIN STAGES AND CHARACTERISTICS OF THE INVESTIGATION

The right control on the technical state and the precise determination of the passing serviceability of carved veneer machines are based on the shown model. It is necessary to solve differential equations which describe the torsional vibrations of the mechanism during the cutting of veneer machine and in a free running. In this way, the mechanical actions, which cause dynamical loading, are connected with vibrations. In order to this, the finding of dependences, which determine these actions as a time functions or movement parameters, defines the accuracy and application of the working model.

Investigations are connected with the solving of some important tasks.

1. First, it is important to find resonance regimes in advance and to investigate the possibility for temporary loss of serviceability passing through them. It can be done on the basis of the working model. This model helps to predict the moving of frequency of free torsional vibrations of the driving mechanism of the carved veneer machines [8]. The possibility for resonance formation is investigated. Some possibilities for construction change or dislocation of resonance regimes are investigated, too.
2. Second, it is necessary to investigate numerically torsional vibrations using the working model. It illustrates actual behavior of the driving mechanism of the carved veneer machine. Different exploitation regimes and work conditions are modeled (Vukov, Vlasev, Todorov and Marinov, 2003). It is very important to introduce the exact values of the investigated process and the parameters of the machines for the accuracy of the numerical solutions.
3. Third, it is necessary to model and investigate parametric torsional vibrations of the driving mechanism of the horizontal carved veneer machine. This investigation is necessary because of the change of the elasticity coefficient of the shafts on which there is an action of torsion and intensive bending. As known, changeable bending moments lead to periodical change of the elasticity coefficient of the shafts' torsion. In differential equations this fact is recognized by introducing of mainly changeable coefficient C_{III}* (Vukov, 2005). The stiffness of the shaft includes the component C_B which depends on the bend:

$$\frac{1}{C_{III}*} = \frac{1}{C_{III}} + \frac{1}{C_B} \qquad (2)$$

The definition of the component C_B requires analyzing of characteristics of shaft material as well as its constructive formation involving its additional elements. Geometric characteristics (length, mass inertia moment), bearing, the way of movement of the secondary mechanisms are rendered an account. The kind and the peculiarity of the changeable bending moments are also significant. The research indicates that the moments are periodical. Their frequencies are equal or multiple to the frequency of rotation of flywheels. For practical accounts it can be assumed:

$$C_B = \frac{EI}{k_1 L \sin k_2 \omega t} \qquad (3)$$

Where E is Young's module,

I – axis inertia moment of the shaft,

k_1 и k_2 – coefficients rending an account of peculiarities of the construction and the work regimes,

L – length of the shaft,

ω_I – rotational frequency of the flywheels.

Practically, the results of the investigation indicate regimes in which breaking of the movement steadiness of the tool slide can be achieved and this can lead to changing for the worse of the technical-indexes of the machine.

4. Fourth, it is necessary to find and investigate amplitude – frequency spectrum of the torsional vibrations. Therefore, a computer simulation model is built on the base of the working dynamical model. This simulation model uses Simulink for Matlab. The results from the simulation model are transformed by Furrier fast transformation. A Matlab program which shows amplitude – frequency spectrum of the torsional vibrations is used (Vukov, 2008). The analysis of this spectrum illustrates a lot of information about processes in the carved veneer machines.

5. Fifth, it is necessary to investigate some of the main defects that are typical for the driving mechanism of carved veneer machines. It is obligatory to form criterion in identification of these defects during the building of the diagnostic model and during the diagnostics. Dynamical processes which are results from the inaccuracy and breakdown in the teeth of the gear drive in the driving mechanism (Vukov, 2009) as well as such in the driving electric motor, in the belt drive and in the thrust bearing of the shaft of the carved veneer machine are investigated (Vukov and Marinov, 2008). The influence of each of these factors on the work of the driving mechanism of the carved veneer machine is estimated.

A scheme which shows the sequence of organizing of investigation is on Figure 4. This scheme indicates stages from a real machine and dynamical – diagnostic model to a computer simulating model. This model is very useful for investigation of torsional vibrations. For define problems, however, it is possible to do only some of the mentioned investigations. During the analysis of the results it is also possible to do some extra investigations (of transition regimes, urgent and breakdown situation). They are modeled using parameters in the model.

The investigation, which uses a computer simulation model, allows investigate the system with a determinate effect on it. This means actions connected with the way and features of its functions. Casual actions which exist in each real investigation and disturb its accuracy are avoided. Results of this investigation can be compared with results of a next investigation of a real object and this can be useful for elimination of casual actions – for example, noise and vibrations from the nearest machine.

By the computer simulation model different zones in work regimes where there is loss of serviceability which is not connected with disturbance in devices can be determined. The occasions are connected with formation of intensive torsional and bending vibrations in some regimes, some defects in the processing material and etc.

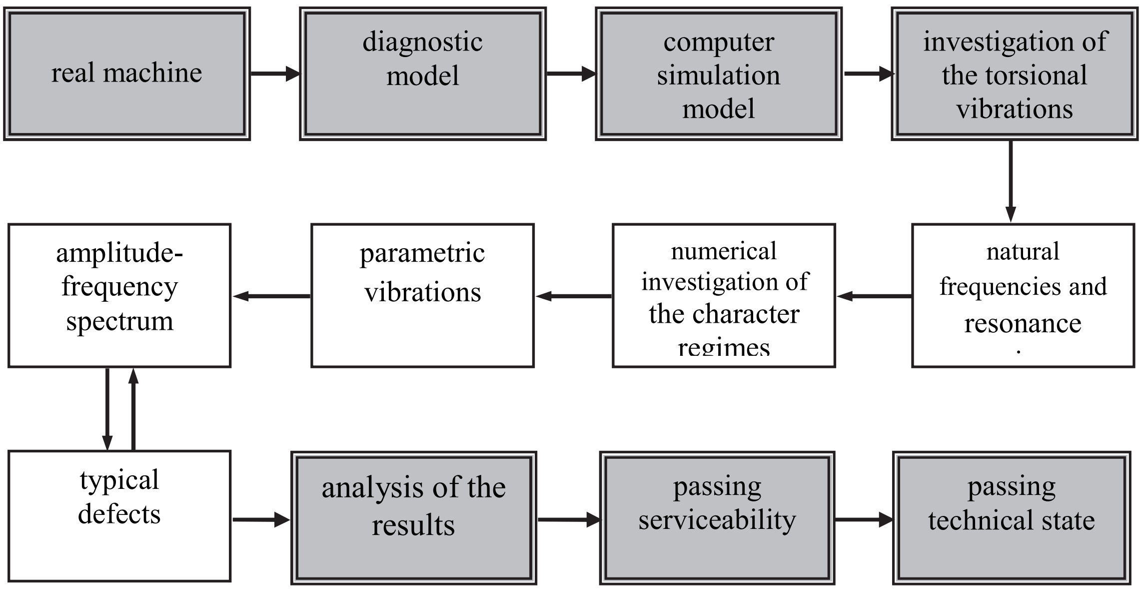

Figure 4. *A sequence of investigations*

The model is also used for evaluation of features and disadvantages of processing wood. The processing material starts vibrating because of the interaction with cutting instruments. Therefore, it becomes a source of noise and vibrations whose characteristics depend on features and disadvantages of processing wood.

The perspective is putting vibrosignals in correspondence to characteristic of processing wood and manufacturing process. Consequently, the application of modern methods of vibrodiagnostics at the state of design and manufacturing allows optimizing the construction achieving economy of money, labour and working time.

4. CONCLUSION

The investigations indicate that the application of vibrodiagnostics on the base of modern computer methods increases the reliability and effectiveness of carved veneer machines. These methods decrease expenses for repair and service. The right determination of the processing serviceability guaranties the quality and accuracy of the final production. As a result, the level of the noise and vibrations that are typical for this kind of manufacturing goes down.

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INVESTIGATION OF MOISTURE CONTENT DISTRIBUTION OF OAK WOOD DURING VACUUM DRYING

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ABSTRACT

The moisture content distribution of oak planks in drying process in a vacuum – type kiln is presented. According to the drying schedule the temperature of the wood in the kiln chamber vary from 15 to 60 ^{0}C during drying.

The planks are kiln dried from initial average moisture content of 40,0 % to final average moisture content 10,0% for a 110 h. Evaluation of the moisture content gradient in the wood is based on differences between surface moisture content of and core moisture content of the planks. Moisture content gradient in the cross section of oak planks is 1,95%. The planks are used for manufacturing of solid wood products.

Keywords: oak, vacuum drying, schedule, moisture content gradient

1. INTRODUCTION

The acceleration of the drying process has always been of great importance. Conducting a drying process at fast way under the vacuum at low temperature of moisture evaporation without deterioration goes to a better understanding of the wood behavior.

The aim of this paper is to present moisture content distribution in the cross – section of a piece of wood . This procedure is integrated with determination both surface and core wood moisture content. Furthermore, a moisture gradient from the outer to the inner layers of the wood will be developed, so the severity of drying process depends on value of moisture gradient.

Adequate drying schedule tends to create such conditions in which there is not much difference between moisture of the wood core and moisture of the wood surface. After all, if the moisture gradient in the wood is too high at the end of drying there are increasing of stresses and dimensional stability is reduced.

2. EXPERIMENTAL METHODS

Three test runs of drying samples of the 50,0 mm oak planks were carried out. For this investigation a total quantity of 1 m ^{3} panks were dried in thicknces of 50,0 mm in widtenss of 8,0 – 26,0 cm Their origin was from Slavonija (Croatia).

The vacuum kiln (Figure 1) consisted of a three wood temperature probes (Figure 2) and three moisture content probes.

The moisture content probes consist six pairs of electrodes planted in three planks with highest initial moisture content (Figure 3).

Figure 4 illustrates the cross section of planks in order to determine moisture content distribution on an oven dry basis.

Figure 1.*Vacuum dry kiln*

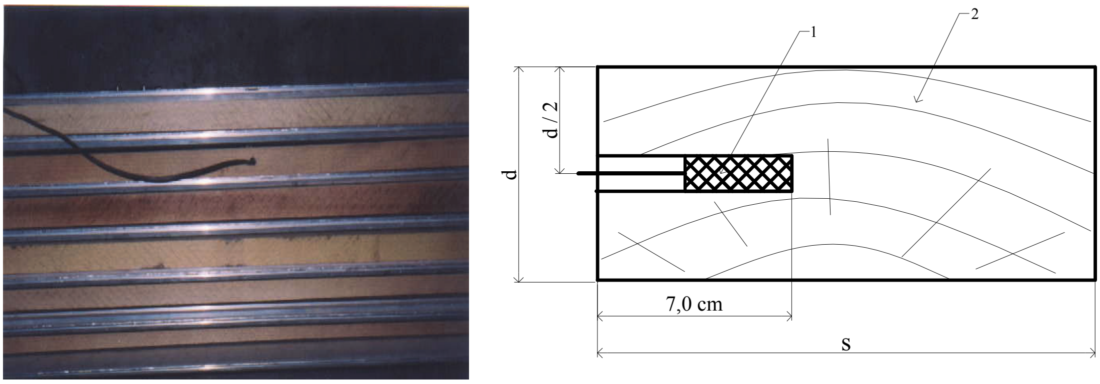

Figure 2. *Sonde for measuring of wood temperature*

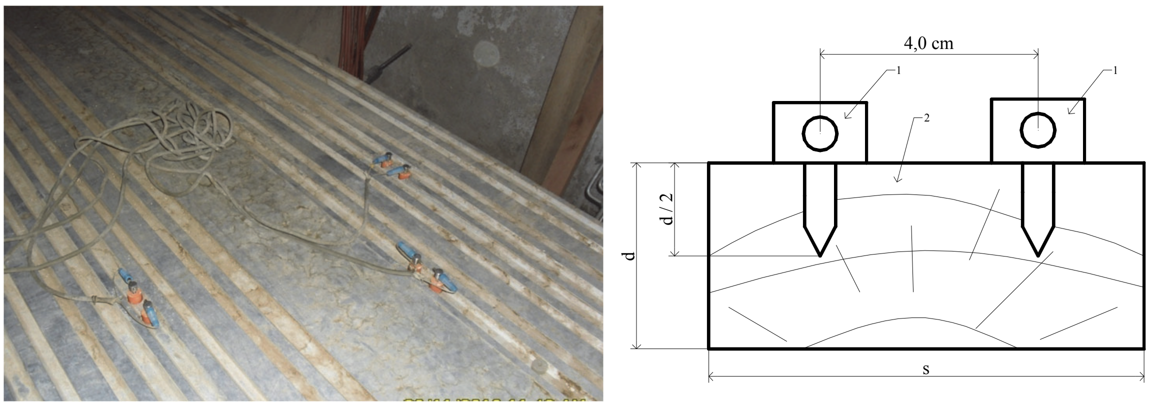

Figure 3. *Electrode for measuring of wood moisture content,*

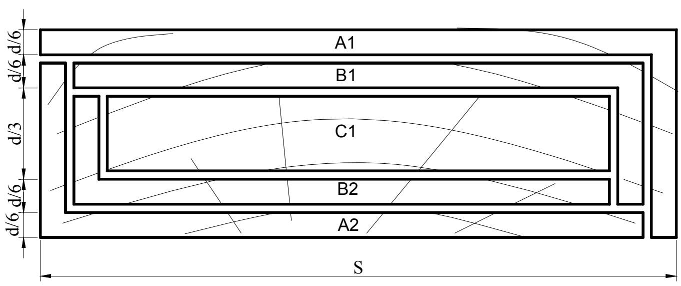

Figure 4. *Slicing test (specimen production)*

3. RESULTS AND DISCUSSION

In order to be able to describe the moisture content distribution of the cross section of a planks it is necessary to use drying schedule according to wood species and wood thikness. After some preliminary experiments, especially in the case of oak in thikness 50,0 mm, the final schedules adopted for the vacuum drying are included in Table 1.

From the regime we can notice that the temperature of the wood during first 12 h rapidly increases from 15 ^{0} C to 52 ^{0} C and reaches its max of 60 on the end of drying. In the same way temperature of heating (heating units) increases from 21 to 57 ^{0} C for 12 h and at the end of drying to max value of 65 ^{0} C. Initial average moisture content of the wood is 40,0 %, and during drying moisture decreases to final value of 10,0 %. Duration of the all drying process is 110 h.

Table 1. *Drying regime of 50,0 mm thick oak planks*

Temperature of heating [^{0} C]	Wood temperature [^{0} C]	Average wood moisture content [%]	Time of drying [h]
25	15	40	0
57	52	37	12
65	60	30	24
65	60	26	36
65	60	23	48
65	60	20	60
65	60	17	72
65	60	14	84
65	60	12	96
65	60	10	110

Table 2 includes the results of the moisture content distributions through the thickness of planks.

Table 2. *Data of moisture content of surface and core of the oak planks*

Wood thickness [mm]	Layer –wood surface	Layer –wood core	Surface moisture content [%]	Core moisture content [%]
50	A		9,85	
	B		10,10	
	A+B		9,97	
		C		11,92

Figure 5 shows that moisture content gradient between surface and core of the planks is 1,95%.Also, it can be concluded that moisture of surface of the planks is 9,85% (layer A) and 10,10 % (layer B), respectively. Average moisture surface content (layers A+B) is 9,97 %. The moisture of the core (layer C) is 11,92 %.

4. CONCLUSIONS

The concept of the vacuum wood drying of oak is successful at an industrial scale. Investigations of moisture content gradient of oak boards 50,0 thick which appears in the vacuum drying process, gives appropriate results for MC distribution in the cross – section of a piece of wood. The MC gradient as predicated occurrence is defined as the difference between the board's core moisture content (MC core) and the board's surface moisture content (MC surface). This provides moisture movement in the drying process. According to drying regime, MC gradient in the oak planks have been presented after drying.

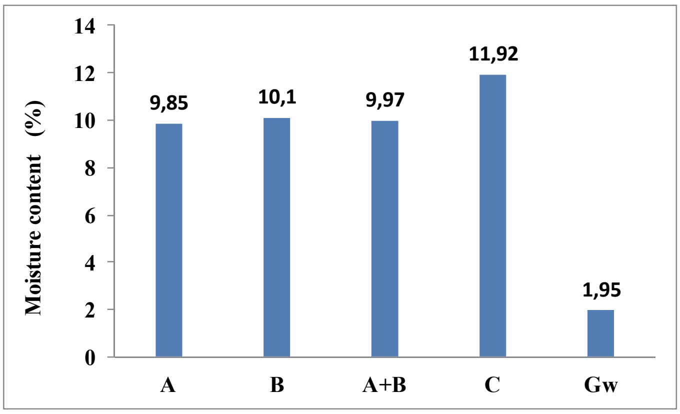

Figure 5. *Wood moisture gradient of the oak planks*

The investigation of the most important technological parameters, characteristics for the process of vacuum drying, has shown the following:
- planks were dried from their initial average moisture content of 40,0 % to final average moisture content of 10,0 % for 110 h.
- temperature of the wood in the drying process increases from 15 ^{0} C to 60 ^{0} C after 24 h and keep constant till to end of the process.
- surface moisture content of planks is 9,97%
- core moisture content of planks is 11,92%.

In the process of vacuum drying of oak planks, a moisture content gradient of 1,95 % has been reached by drying process. It means that obtained results for moisture content distribution in the cross – section of a piece of wood are in agreement with production of solid wood construction details.

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UDC 674.9

COMPARATIVE STUDIES ON THE ADHESION OF DIFFERENT TYPES OF DECORATIVE ELEMENTS TO THE FACIAL SURFACES OF VENEER AND LAMINATED FURNITURE BOARDS

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ABSTRACT

The possibility of decorating the facial surfaces of furniture veneer and laminated particle board was investigated. For this purpose are used duraluminium bands, polyvinyl chloride (PVC) edge banding and solid beech wood. For the bonding are used three one-component, two two-component adhesives and double sided adhesive mounting tape. Gluing is done at room temperature with press force in the range of 0,2-0,4 MPa. The results showed that the most appropriate for this purpose is polyvinyl acetate glue („Selt").

Key words: furniture board, chipboard, decorative element, glue, adhesion

1. INTRODUCTION

One of the methods for decorating furniture facial surfaces is bonding of decorative elements made of different materials (metals, metal alloys, plastics, solid wood, metalized plastic, metalized wood etc.) with band form. The fixing of these elements to the substrate also can be performed by nailing (Kavalov 2000, Panayotov 2010). The main disadvantage of joining by nailing is low tensility. Therefore, adhesion can be determined like more promising and comprehensive method and in some cases as an inevitable alternative to solve specific problems. The most significant problem in this method for attaching the decorative elements is the sustainability of the object's shape and fixing the element to the base surface. Often because of different materials occur strains leading to distortion and poor adhesion (Panayotov 2002). For this reason, the purpose of this investigation is to examine the possibility of attachment of different decorative elements with different types of adhesives.

2. METHODOLOGY

Because of poor information some preliminary tests were made. Their purpose is to define the unclear parameters (quantity and type of adhesive, pressing and curing time). These studies showed that a significant impact have pressing time and curing time.

From an economic point of view and account of available materials in the trade network for decorative elements as an object for experiment were selected: polyvinyl chloride edge banding, duraluminium and solid beech bands. Gluing is done with the following adhesives: polyvinyl acetate - „Selt", Selt Ltd., Bulgaria (www.selt.bg); epoxy-„Poxipol", Adefal Trading SA, Uruguay; polyacrylate-„Power Fix", Henkel, Germany (www.actual-industries.com); two-component polyurethane-„Bisonite", Bison International, France (www.profix.bg); chloroprene-„Helmeteks", Chavdar Ltd., Bulgaria; double sided adhesive mounting tape with primary binder such as polyisobutylene-3M, USA. Press force is done with hand screw clamps providing a pressure range from 0,2 to 0,4 MPa.

To produce the bonded joints are used details of laminated and veneer (oak veneer) chipboard with size-500/30/10 mm. The chosen decorative elements sizes are: beech bands-500/20/8 mm, duraluminium strip-500/20/2 mm and PVC edge banding-500/21/2 mm. Variants of the conducted experiments are shown in Table 1. Some of the preparations for obtaining sampling units can be seen in Figure 1. The different bases (VCb/LCb) are made by cross-cutting chipboards with sizes 550/500 mm. The details of the laminated chipboard are grinded with sandpaper (N 180) and cleaned. All types of decorative elements are made by cross-cutting with desk type band saw (or metal scissors) of longer details with the same cross section. Other operation for the metal and PVC elements is surface cleaning of greasy stains, dust, fingerprints, etc.

Table 1. *The variants for bonding: bases, decorative elements, adhesives and pressing durations VCb- Veneered Chipboard, LCb- Laminated Chipboard*

N	Base	Decorative element	Adhesive	Pressing duration (h,min)
1	LCb	Solid wood	„Selt”	45 min
2	LCb	PVC edge banding		45 min
3	LCb	Duraluminium		45 min
4	VCb	Solid wood	„Selt”	25 min
5	VCb	PVC edge banding		45 min
6	VCb	Duraluminium		45 min
7	LCb	Solid wood	„PowerFix„	2 h
8	LCb	PVC edge banding		12 h
9	LCb	Duraluminium		12 h
10	VCb	Solid wood	„PowerFix„	2 h
11	VCb	PVC edge banding		2 h
12	VCb	Duraluminium		2 h
13	LCb	Solid wood	„Poxipol”	15 min
14	LCb	PVC edge banding		15 min
15	LCb	Duraluminium		15 min
16	VCb	Solid wood	„Poxipol„	10 min
17	VCb	PVC edge banding		15 min
18	VCb	Duraluminium		15 min
19	LCb	Solid wood	„Bisonite„	1 h, 15 min
20	LCb	PVC edge banding		1 h, 15 min
21	LCb	Duraluminium		1 h, 15 min
22	VCb	Solid wood	„Bisonite„	1 h, 15 min
23	VCb	PVC edge banding		1 h, 15 min
24	VCb	Duraluminium		1 h, 15 min
25	LCb	Solid wood	Double sided adhesive mounting tape	3 min
26	LCb	PVC edge banding		3 min
27	LCb	Duraluminium		3 min
28	VCb	Solid wood	Double sided adhesive mounting tape	3 min
29	VCb	PVC edge banding		3 min
30	VCb	Duraluminium		3 min
31	LCb	PVC edge banding	„Helmeteks„	3 min
32	VCb	Solid wood	„Helmeteks„	3 min

After joining the two elements are placed between two chipboards with size 600/50/18 mm and pressed with 4 screw clamps for more uniformly and distributed load along the length. After a certain period of time the glued details are released and placed in a storage room with an average relative humidity w≈47% and temperature t≈23 °. Before cutting the preparations are stored for 5-6 days and every 24 hours their distortion is measured by metal line with micrometer.

***Figure 1.** Preliminary preparations for the sampling units*

As in preliminary experiments and most operations here for making sampling units is used circular saw. The saw disk should be submitted over the table at a height equal to the thickness of the chipboard. The method is shown schematically in Figure 2.

The order of operations is as follows:

1. First produced rabbet at the top of the detail. Then performed a series of cross-cuttings with consistent position change to the circular saw (Figure 2.1).
2. Test fixtures are done by cutting the decorative elements (Figure 2.2) with desk type band saw for wood or polyvinyl chloride cutting and grinder machine for duraluminium cutting. The last operations are: cleaning, numbering and measuring the size.

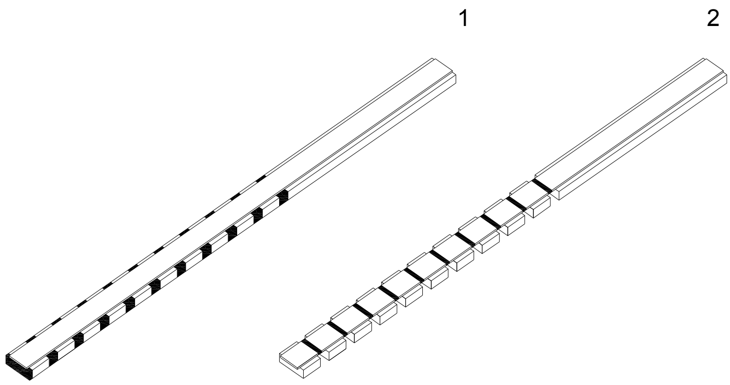

***Figure 2.** Scheme of cutting to obtain sampling units*

The scheme on Figure 3 shows size of the sampling units. On Figure 4 is illustrated one of the variants. The difference between the combinations is only the thickness of the decorative element: solid wood-8mm and polyvinyl chloride/duraluminium-2mm.

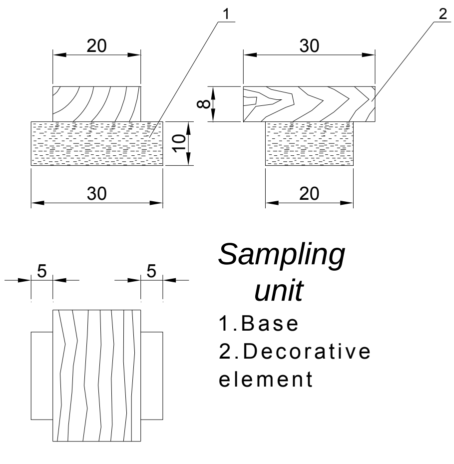

***Figure 3.** Scheme of sampling units*

***Figure 4.** A group of sampling units with laminated chipboard base and decorative element of polyvinyl chloride*

To assess the obtained results is used a special method. When choosing a methods for assessing the quality of adhesive joints are preferred following indicators: workability of the adhesives, pulling strength of the decorative elements, sustainability of the objects shape, duration of pressing and glued joint price. The obtained values are converted to the grades. For each of the indicators is determined weight coefficient. After that for each option is calculated complex qualitative assessment by the formula:

$$K_\kappa = \frac{\sum B_i K_{mi}}{\sum K_m}, \ (1)$$

Where K_k is complex qualitative assessment,
B_i-grade of the "i"-th parameter,
K_{mi}-weight coefficient on the "i"-th parameter.

The grades are formed depending on obtained quantitative or qualitative valuesfor the respective criterion. Weight coefficient is determined depending on the importance of indicators of the overall technological process and the quality of the final product.

The workability of the adhesives largely depends on availability of preliminary preparation and application of the adhesive mixture. Therefore, the adhesives with more than one component can be defined as less workable than those who are ready for application (without additional operations). On the other hand, the viscosity of different adhesives affects the easiness in application of the materials. In assessing the workability is taken into account ways of cleaning excess adhesive i.e. the easiness of its removal. Not least in severity is the presence of toxic substances in the adhesives.

Figure 5. *Test machine*

Figure 6. *Test devices*

The duration of pressing is determined by the period which the joined elements remain in tight position. In determining this duration are taken into account the results of preliminary tests, information from the manufacturer and practical experience.

The cost of the adhesive joint depends on the ratio price-quantity and consumption per unit surface. As a benchmark is adopted the cost price for gluing a decorative element with a width of 20 mm and a length of 1m.

To test the strength of bonding was used testing machine with the possibility of measuring values up to 50 000 N- Model R 5, 1981 (Figure 5). Production of "Mashinpriborintorg" USSR. The loading is done with speed of 20 $mm.min^{-1}$. The accuracy of measurement under load is within the range of ± 1%. The test is performed by a methodology borrowed from standard BDS EN 319:2002.

Attachment of sampling units to the test machine is made by specially designed and constructed devices shown in Figure 6. The jaws are fixed perpendicular to each other to the chucks of the testing machine. The test unit is placed between the top and bottom jaws so that contact is made only on the side of the bonding of different materials. The kind of destruction (Panayotov 2002) is reported in percent (Fig. 7).

Based on reported values when tested perpendicular to the adhesive layer a statistical analysis is done. For each group of test units is calculated respectively: average value $\overline{x}$, dispersion S_{x^2}, standard deviation S_x, the difference between the highest and lowest value R, standard error m_x, coefficient of variation V_n, accurate indicator p_x.

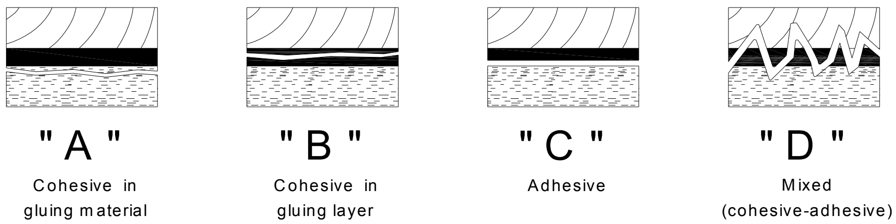

Figure 7. *Possible ways for demolition of sampling units*

3. RESULTS AND DISCUSSION

The example on Figure 8 shows that the destruction occurs at the base (chipboard). This indicates that bonding strength have values significantly greater than the tensions limit on transverse destruction strength of the chipboard.

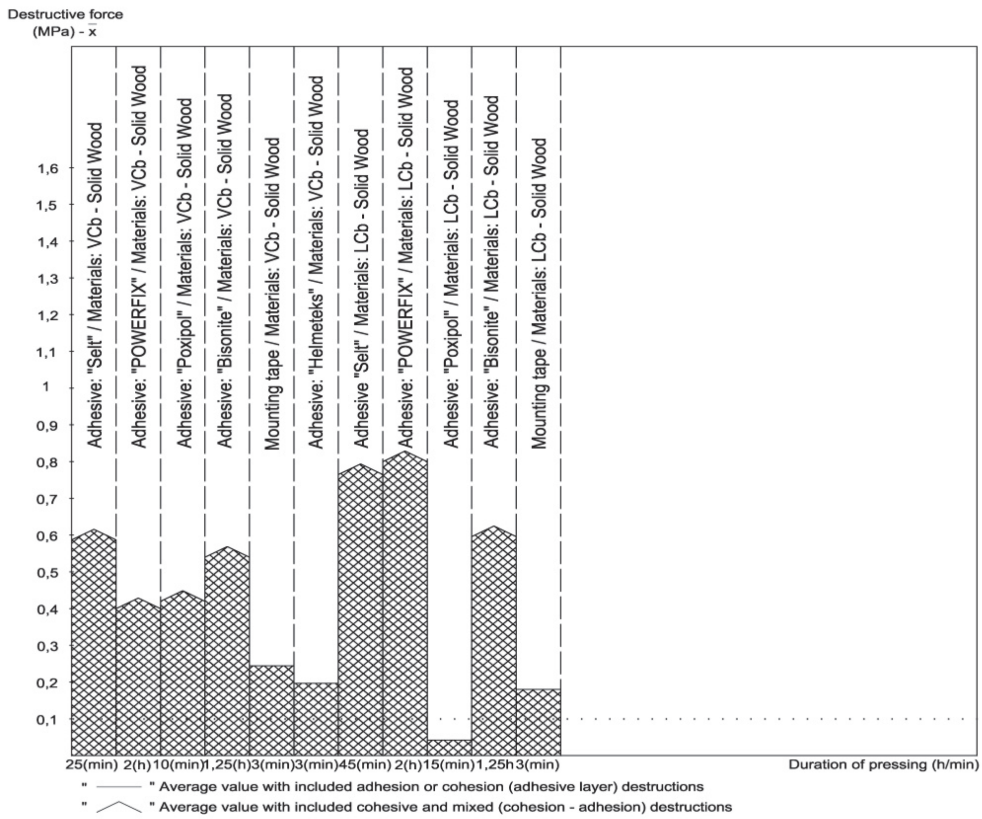

Figure 8*. Tensile strength perpendicular to the adhesive layer*

In Figure 9 is represented graphically one of the options in which can be clearly seen that the values of distortion change with time. This is because the different preparations of test units are not kept at constant temperature and relative humidity. The allowed value for distortion of facial surfaces of the furniture is millimeter per linear meter (1 mm/m '). However, the graphs show that in most cases the normative is exceeded. The main reason for this is low ratio between the size of the base surface and the part with adhesive. The default value of the sustainability of the objects shape is after 72 hour storage or the next closest. The results where the distortion is directed to the base are marked with "+" and those directed to decorative elements with "-". As a benchmark value is accepted the one that would result in parts with a length of 1 m' and width 20 mm. Because of the unavoidable influence of side factors a general conclusions in terms of distortion could not be made. Fact is that in most of cases the glue with a higher percentage of dry residue such as „Poxipol” (epoxy), „Bisonite” (polyurethane) show better resistance to distortion than „Selt” (polyvinyl acetate) and „Power Fix” (polyacrylate) whose solvent is based on water.

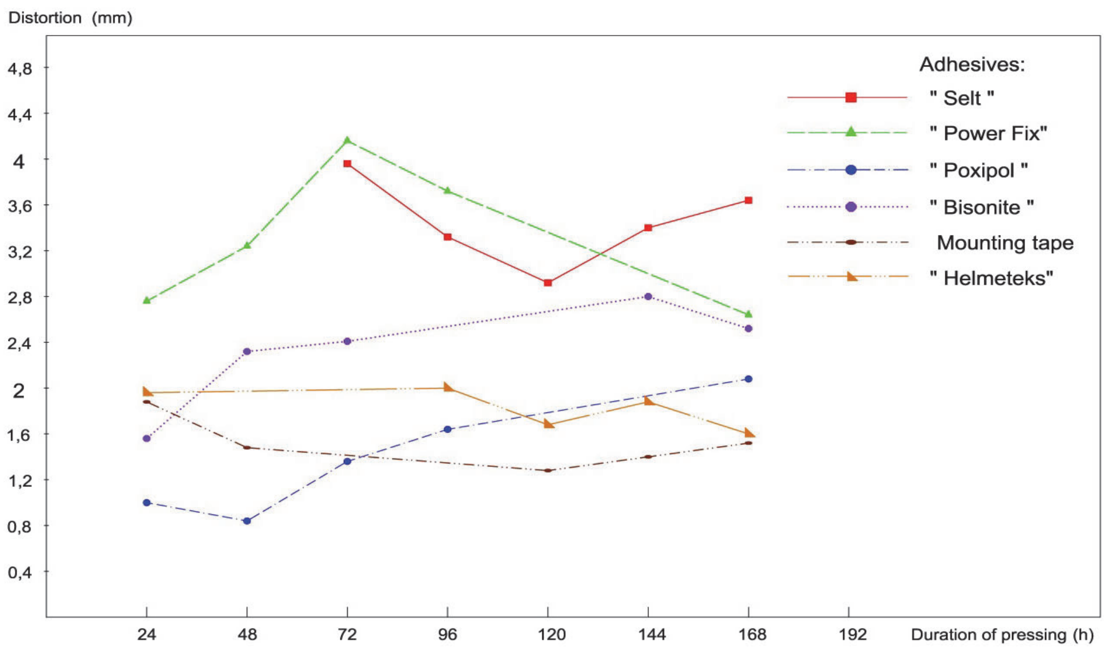

Figure 9. *Graph showing the distortion of variant-laminated chipboard base and decorative element of polyvinylchloride*

Contrary to the previous two criteria, workability of the adhesives doesn't depend on gluing material variants. On this indicator the glue „Power Fix” surpasses the other adhesives. This is because of its pasty form and the possibility to reposition the bonded elements within 5-10 min. The polyvinyl acetate glue also doesn't require prior preparation. Its only disadvantage is its low viscosity i.e. has high running ability. This property of the adhesive isn't a major problem because after exercising pressure the excess is easily removed with a damp cloth.

The two-component adhesives require prior preparation of the adhesive mixture. Bonding of decorative elements with elongated shape is extremely difficult with glue „Poxipol”. The reason for this is the short curing times after mixing of the components and the inability of the adhesive to be applied evenly. This makes it almost impracticable for some variants of adhesion.

The technological difficulties with glue „Helmeteks” are determined mostly by its low viscosity and that should be applied to the adhesive surfaces of both elements.

From the foregoing should be expected that double sided adhesive mounting tape is the most technological product. However, during the working process were found some minor complications: missing any possibility of repositioning, possibility to breakage when fixing to one element.

When determining the cost price can be clearly seen that this indicator glue "Selt" is a leader than others adhesives. Adhesives „Power Fix” and „Helmeteks” get lower values and can be defined as relatively cheap. The two-component adhesives „Poxipol” and „Bisonite” perhaps because of the active advertising policy the manufacturing companies or difficult synthesis receive higher values for this indicator and they are defined as expensive. Most impressive is the price of double sided adhesive mounting tape which is unacceptably high compared to the unsatisfactory strength characteristics.

Regarding the criterion duration of pressing double sided adhesive mounting tape gets the best grade score. The same applies to glue „Helmeteks” in which the details with adhesive remain in „open position” before pressing. In this way the solvent in adhesives goes faster in a gas state and significantly reduces the curing process. Glue „Poxipol” also has good performance in terms of time pressing. Fact is that this advantage becomes a disadvantage in the criteria for technology and strength. The accepted time limits for polyvinyl acetate adhesive are: in option VCb/Solid wood-25 min and 45 min for all other combinations of materials. This is because of the small width of the adhesion to the base details. In this way the water which is the solvent is leaving easily the adhesive.

In polyurethane adhesive even in carrying out preliminary tests is established that the type of materials doesn't play a significant role in determining the duration of pressing. Fixed period of time for all combinations of materials is 1,25 h which could be considered as good in small and medium enterprises. As a worst adhesive in terms of this indicator is „Power Fix” which duration of pressing for bonding materials LCb/Duraluminium and LCb/PVC edge banding is 12 h.

Based on the described criteria and taking into account the examined methodology is calculated a complex qualitative assessment. The results are shown in Tables 2, 3, 4, 5, 6 and 7. In the case of score 5 for some combinations adhesive-materials it is considered practically not applicable i.e. scrapped.

Table 2. *Weight coefficient and complex qualitative assessment*

N	Base	Decorative element	Adhesive	Weight coefficient					Comprehensive quality assessment (K_k)
				Workability $K_{w.}$ **3**	Tensile strength $K_{t.s.}$ **4**	Shape sustaina-bility $K_{s.s.}$ **4**	Pressing duration $K_{p.d.}$ **2**	Cost price $K_{c.p.}$ **3**	
				Valuation results					
1	VCb	Wood	“Selt”	1	0	1	1	0	0,56
2	VCb	Wood	“PowerFix”	0	0	4	2	1	1,44
3	VCb	Wood	“Poxipol”	4	0	1	1	2	1,50
4	VCb	Wood	„Bisonite”	2	0	1	2	2	1,25
5	VCb	Wood	M. tape	1	3	**5**	0	4	
6	VCb	Wood	„Helmeteks”	2	4	3	0	1	2,31

Table 3. *Weight coefficient and complex qualitative assessment*

N	Base	Decorative element	Adhesive	Weight coefficient					Comprehensive quality assessment (K_k)
				Workability $K_{w.}$ **3**	Tensile strength $K_{t.s.}$ **4**	Shape sustaina-bility $K_{s.s.}$ **4**	Pressing duration $K_{p.d.}$ **2**	Cost price $K_{c.p.}$ **3**	
				Valuation results					
1	VCb	Wood	“Selt”	1	0	2	2	0	0,94
2	VCb	Wood	“PowerFix”	0	0	3	2	1	1,19
3	VCb	Wood	“Poxipol”	4	0	2	1	2	1,75
4	VCb	Wood	„Bisonite”	2	0	3	2	2	1,75
5	VCb	Wood	M. tape	1	4	**1**	0	4	2,19

Table 4. *Weight coefficient nd complex qualitative assessment*

N	Base	Decorative element	Adhesive	Weight coefficient					Comprehensive quality assessment (K_k)
				Workability $K_{w.}$ **3**	Tensile strength $K_{t.s.}$ **4**	Shape sustaina-bility $K_{s.s.}$ **4**	Pressing duration $K_{p.d.}$ **2**	Cost price $K_{c.p.}$ **3**	
				Valuation results					
1	VCb	Alum	“Selt”	1	0	0	2	0	0,44
2	VCb	Alum	“PowerFix”	0	0	**5**	2	1	
3	VCb	Alum	“Poxipol”	4	0	4	1	2	2,25
4	VCb	Alum	„Bisonite”	2	0	2	2	2	1,50
5	VCb	Alum	M. tape	1	3	3	0	4	2,44

Table 5. *Weight coefficient and complex qualitative assessment*

N	Base	Decorative element	Adhesive	Weight coefficient					Comprehensive quality assessment (K_k)
				Workability $K_{w.}$ **3**	Tensile strength $K_{t.s.}$ **4**	Shape sustaina-bility $K_{s.s.}$ **4**	Pressing duration $K_{p.d.}$ **2**	Cost price $K_{c.p.}$ **3**	
				Valuation results					
1	LCb	PVC	“Selt”	1	0	**2**	2	0	0,94
2	LCb	Wood	“PowerFix”	0	0	**2**	2	1	0,94
3	LCb	Wood	“Poxipol”	4	**5**	2	1	2	
4	LCb	Wood	„Bisonite”	2	0	0	2	2	1,00
5	LCb	Wood	M. tape	1	3	3	0	4	2,44

Table 6. *Weight coefficient and complex qualitative assessment*

N	Base	Decorative element	Adhesive	Weight coefficient					Comprehensive quality assessment (K_k)
				Workability $K_{w.}$ **3**	Tensile strength $K_{t.s.}$ **4**	Shape sustaina-bility $K_{s.s.}$ **4**	Pressing duration $K_{p.d.}$ **2**	Cost price $K_{c.p.}$ **3**	
				Valuation results					
1	LCb	PVC	“Selt”	1	0	**5**	2	0	
2	LCb	PVC	“PowerFix”	0	0	**5**	4	1	
3	LCb	PVC	“Poxipol”	4	**5**	1	1	2	
4	LCb	PVC	„Bisonite”	2	0	4	2	2	2,00
5	LCb	PVC	M. tape	1	4	2	0	4	2,63
6	LCb	PVC	„Helmeteks”	2	4	2	0	1	2,06

Table 7. *Weight coefficient and complex qualitative assessment*

N	Base	Decorative element	Adhesive	Weight coefficient					Comprehensive quality assessment (K_k)
				Workability $K_{w.}$ **3**	Tensile strength $K_{t.s.}$ **4**	Shape sustaina-bility $K_{s.s.}$ **4**	Pressing duration $K_{p.d.}$ **2**	Cost price $K_{c.p.}$ **3**	
				Valuation results					
1	LCb	Alum.	“Selt”	1	0	4	2	0	1,44
2	LCb	Alum.	“PowerFix”	0	0	2	4	1	1,19
3	LCb	Alum.	“poxipol”	4	4	1	1	2	2,50
4	LCb	Alum.	„Bisonite”	2	0	2	2	2	1,50
5	LCb	Alum.	M. tape	1	3	1	0	4	1,94

The results of a complex qualitative assessment of different adhesives with the exception of „Poxipol”, show that the type of adhesives is not important for the strength of the adhesive joint. Taking into account already mentioned side factors in criteria shape sustainability follows that the analysis of complex qualitative assessment for each option individually isn't the most appropriate. Precisely those reasons allow to make a general classification to used glues:

1. In 67% of the variants „Selt” surpasses other adhesives. This is because of its low cost, high workability and the strength of the adhesive joints;
2. Little shrinkage of the adhesive in glue „Bisonite" which is its biggest advantage over other adhesives put it in second place;
3. On third place is „Power Fix” whose main disadvantages are the duration of pressing and shape sustainability of glued details;

4. Mainly because of its poor workability the glue „Poxipol" is inappropriate variant to join some of the considered options (Example: LCb/ PVC);

5. Preliminary considered as inappropriate glue „Helmeteks" shows relatively good shape sustainability. It also has low cost price but because of the low strength of the adhesive joint is ranked fifth;

6. Regardless of its good workability, because of the extremely high price and low strength, double sided adhesive mounting tape becomes inappropriate choice for decorating with such type of decorative elements. For these reasons, its variations are taking the last place.

4. CONCLUSION

Based on the results can be made the following conclusions and recommendations:

1. In cases of doubt about the strength of adhesion variants and with lower values of the ratio between the areas of the base-adhesive layer is recommend a polyurethane adhesive „Bisonite". For this glue the distortions are with low values because it has a high percentage of dry residue. It should be noted that its use in series production would require additional investments in terms of the ventilation. This is because of the fact that the used binder is isocyanate which is a toxic substance;

2. As a possible substitute for the glue „Bisonite" to large decorative elements and in cases where the duration of pressing is not essential is recommended to use the epoxy glue „Poxipol". However, the density and resiliency of the adhesive mixture should not be forgotten. As already mentioned, they create problems in its application especially for long parts;

3. In cases where the duration of pressing isn't important is possible to use the glue „Power Fix". However, high levels of distortion resulting from its use should be considered. But because of the fact that most of the decorative elements are with narrow size make it a good choice;

4. Preliminary experiments with grinding of bonding surfaces show that this operation should become mandatory in cases of regular production;

5. In all cases, regardless of the basis or used glue for the correct fixing of decorative elements on the substrate it's imperative to use a template. This is because to the fact that the fixing precision of decorative elements such as those considered in the study is the most important quality factor.

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NOVEL TYPES OF WOOD COMPOSITE MATERIALS MODIFIED WITH LIQUEFIED WOOD

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ABSTRACT

Wood is one of the most abundant and accessible renewable resources available to men. With growing emphasis on sustainable development, new methods involving alternative wood use are being explored. An approach that has been intensively researched in recent years is wood liquefaction, with the aim of converting wood material in a biodegradable polymer materials and increase the percentage of wood utilization. In previous years, the researchers were liquefied chemical wood components such as cellulose, hemicellulose and lignin in liquid bioactive materials. Wood liquefaction is based on the fact that the wood components are chemically derivatised, thus increasing their solubility in certain solvents which dissolved macromolecules can subsequently used for the preparation of useful polymer materials, or macromolecules are partially decomposed into smaller soluble oligomers which are then used as a source of raw materials for further use. Particularly interesting is the use of liquefied wood as a source of raw materials from which can be produced various wood composite materials (particleboard, fibreboard panels, MDF, WPC and others), and therefore replace some synthetic polymers based on the conventional source - oil. Therefore, the aim of this paper is to give an overview of using liquefied wood in synthetic resins modification as a raw materials for the novel types of composite materials production.

Keywords: liquefied wood, wood composite materials, resin modification

1. INTRODUCTION

Development of the novel types of materials at the beginning of the new millennium certainly can not be imagined without renewable resources. Biomass or lignocellulosic materials are very important natural renewable resource or raw material. Wood, as a dominant biomass resource, is the most commonly used material among all the "engineering" materials. As a consequence, wood takes place of great importance in the global picture of available raw material resources.

Wood composite materials, respectively particleboards, fibreboards, plywoods, oriented strand boards (OSB), wood-plastic composites (WPC), high pressure laminates (HPL) and other, are materials of future. With their wide spectra of potential applications these materials occupy almost all fields of usage. Their technological flexibility is not just following modern trends, but is primal impulse and pathway for acquisition of new trends. Quality of wood composite materials does not exclusively depend on wood species and their properties applied in production, but with application of sophisticated technologies, composite quality is designed according to utilisation demands (Jambreković et al., 2005).

In group of wood composite materials, valueless wood biomass and residues after usage are converted to valuable material, which can be competitive in furniture, construction, shipbuilding and other industries. The main advantage of wood composites is application of uncompetitive wood species and forest sortiments without technical values (fuel wood, small-sized technical wood, waste like stem residues, branches, stumps, and other), appliance of industrial residues (wood residues from primary and secondary sawmill, wood residues from veneers and panels production, and other), and recycling possibility of wood and wood residues after usage (used furniture and construction wood) (Jambreković et al., 2006; Medved et al., 2010).

Production of polymers, such as synthetic resins, has long relied on fossil resources to provide raw materials. The global use of polymers has experienced decades of consistent growth and is showing no signs of reduction, especially as developing countries are poised to increase their per capita consumption. However, increasing concerns have been raised with this massive consumption of fossil oil. First of all, usage of fossil oil is considered a big contributor to increase the level of carbon dioxide (CO_2), the major part of greenhouse gas, which is directly associated with the global warming and climate change (Antonović et al., 2007; Naik et al., 2010). Furthermore, disposal of polymer waste and its incompatibility with nature is another highly visible environmental problem because the synthetic polymers are highly resistant to natural degradation. In addition to the environmental issues, the growth in polymer consumption and the ultimate problem with petroleum based materials is in principle limited by finite oil reserves and increasing demand in both developing and developed countries, which has caused the incresing of the price of petroleum products. The solution to this problems could be increasing the use of renewable resources used for energy and chemicals such as for polymer production (Antonović et al., 2010a; Španić et al., 2010; Pan, 2011; Medved et al., 2011a).

Synthetic resins for wood composite materials are absolutely non-wooden components in their production. As we mentioned earlier, raw materials for these resins come from non-renewable oil and natural gas. Nowadays, these resins are mostly formaldehyde based, like phenol-formaldehyde (PF) and urea-formaldehyde (UF) resins, and are dominant on the market of resins for wood composites. Although, in this moment, there is no problems with supplying with those raw materials, development of resins from renewable natural sources will ensure long term success in wood composite industry. It will also reduce potential negative influence of oil prices, ultimately restricted oil and natural gas delivering (Antonović et al., 2009b; Medved et al., 2011b).

Linked to above, many researches are focussed on wood liquefaction and using liquefied wood as natural resins. Wood liquefaction is novel method, its aim is to convert wood material in biodegradable polymer materials and increase percentage of wood utilisation. With the application of natural resins, the problem with formaldehyde emission, present in composites produced with application of synthetic formaldehyde adhesives, will be eliminated. That would cause enhancement of ecological purity of wood composite materials, and further expansion of integral wood components utilization (Antonović et al., 2010b).

At the present time, the most attention attracted wood (biomass) liquefaction in presence of some organic reagents and their application in preparation of resins for wood composites. The most interesting are two wood liquefaction methods. First one is preparation in presence of phenol, which resulted with liquefaction products rich with phenol units, so it could be applied in phenol resins preparation (similar to conventional phenol resins), mouldings and other. Second liquefaction method was achieved in presence of alcohols, especially polyhydric alcohols, and gained products can be used as polyols for preparation urea- and melamine-formaldehyde, polyurethane and epoxide resins (Antonović, 2009b).

The focus of this paper is to give an overview on using the liquefied wood in modification or synthesization different categories of synthetic resins as a raw materials for the novel types of composite materials production.

2. WOOD LIQUEFACTION

Wood chemical components possess many active functional groups susceptible to reaction. These reaction sites or functional groups are primary and secondary hydroxyls, carbonyls, carboxyls (ester), carbon-carbon, ether, and acetal linkages. Virtually every type of reagent capable of reacting with these functional groups can be applied to wood, and the literature is full of examples. Hence, based on the variety of functional groups, etherification, esterification, alkylation, hydroxyalkylation, graft copolymerization, cross linking, and oxidation have been conducted to produce a series of products with many applications (Hon, 1996).

One approach, that has been researched last two decades, is to chemically derivate the wood components and thus increase their solubility in selected solvents. The dissolved macromolecules are then used in preparing useful polymeric materials. Another approach is to partially degrade the macromolecules to smaller soluble oligomers which are then used as feedstock for further use. Very often both methods overlap slightly, meaning that a limited degree of degradation takes place during the derivation and/or dissolution process. Such is indeed the case in wood liquefaction in which wood reacts with different types of reagents under elevated temperatures and in the presence of catalysts to yield a liquid product mixture known as liquid wood (Antonović, 2009a).

Liquefaction comprises a complex set of reactions taking place on the polymeric components of wood. They include derivatization such as esterification or etherification of free hydroxyl groups in cellulose or lignin as well as reactions that break the polymer chain of cellulose. In addition, liquefaction is affected by physical constraints on wood reactivity such as the high crystallinity of cellulose. The tight packing of cellulose in the crystalline domains makes the reaction kinetics of otherwise reactive functional groups dependent on the diffusion of reagents into the tightly packed system. To overcome this limitation and speed up the liquefaction, increasingly harsh catalysts and reaction conditions, mainly mineral acids and high temperatures, have been employed.

After the discovery of the wood liquefaction phenomena, researches of different liquefaction parameters were conducted (types and ratios of reagents or solvents, catalysts types, liquefaction times and temperatures, wood or biomass species, anatomical part and sample granulations), in terms of (1) increasing of biomass concentration in liquefaction mixture, (2) achieving the real liquefaction degree with respect to solubility properties of liquefied biomass in organic solvents, (3) comprehension and understanding of the wood liquefaction mechanism, and (4) further application.

At the present time, several solvent systems of wood liquefaction can be identified in the previous researches, and that are processes which use phenols (Lin et al., 1997; Acemioğlu and Alma, 2002; Lee et al., 2002a), cyclic carbonates (Mun et al., 2001; Xie and Chen, 2005), ionic liquids (Honglu and Tiejun, 2006), dibasic esters without hydroxyl groups (Wei et al., 2004), and polyhydric alcohols (Kurimoto et al., 1999; Antonović, et al., 2006). Liquefied wood as a naturally based product has a great potential to be used as an resin/adhesive. It can be used as a part of a polymer formulation, as a part of an adhesive mixture with commercial adhesives, or as an independent material for wood bonding.The majority of attention was dedicated to application of liquefied wood in preparation and modification of resol- (Lee and Liu, 2003) and novolac-type phenol-formaldehyde resins (Alma et al., 1996; Lee et al., 2002b; Santana and Baumann, 1996; Hassan et al., 2009), urea-formaldehyde resins (Antonović, 2008; Antonović et al., 2009a; Antonović et al., 2009b; Antonović et al., 2010a), melamine-formaldehyde and melamine-urea-formaldehyde resins (Kunaver et al., 2010a), polyurethane resins (Kurimoto et al., 2000; Kurimoto et al., 2001; Wei et al., 2004; Kunaver et al., 2010b) and foams (Yao et al., 1996; Alma and Shiraishi, 1998; Lee et al., 2002c), saturated and unsaturated polyesters, isocyanate (Tohmura et al., 2005) and epoxy resins (Nonaka et al., 1997; Kobayashi et al., 2000; Kobayashi et al., 2001; Xie and Chen, 2005), coatings (Budija et al., 2009a; Budija et al., 2009b) and their further application in novel types of composite materials, which have potential application in the wood industry. However, liquefaction reactions with phenols and polyhydric alcohols are the most interesting in the previous researches and literature.

2.1 Wood liquefaction with phenol

Several previous studies on the mechanism of wood components liquefaction with phenol were introduced. They showed that the phenolysis of wood components in the presence of an acidic catalyst resulted in dozens or even hundreds of different reactions that compete with each other. The mechanism of polysaccharides liquefaction (cellulose and hemicellulose), which are the main substance of wood quantity, happens with phenol using catalyst, through phenolysis of glucosidal bond. Appropriate glucosids were obtained through polysaccharides liquefaction with phenol. The reaction between polysaccharides and phenols is more complex than the reaction between polysaccharides and alcohols. The cause is phenol properties. Using phenols we develop substances with higher molecular weight, which prolong reaction time. The polysaccharides liquefaction time depends on solvent properties (Tišler, 2002; Grbac et al., 2003).

Zhang et al. (2006) explored the mechanism of cellulose liquefaction in phenol. They indicated that pyranose, resulting from cellulose decomposition, can be combined to form the phenol hydroxyl and benzyl derivatives, which retained the characteristic phenolic functional groups.

Furthermore, due to the degradation of lignin in the presence of phenol, a variety of phenol compounds such as guaiacol, coniferyl alcohol, vanillin, etc. occur. Lignin liquefaction mechanism in the presence of phenol was studied with acid catalysts as well without them. They chose a model lignin component, guaiacil glycerol-β-guaiacil ether (GG), and found that guaiacol, which was formed during the degradation of GG at high temperatures without catalyst, homolitically dissolve to different radicals, which are capable for binding with phenol and formaldehyde (Lin et al., 1997).

Acemioğlu and Alma (2002) explored the kinetics of the wood phenolysis reaction in the presence of HCl as catalyst at a temperature of 60-150 °C during different reaction time. The results showed that about 90 % of wood can be liquefied in phenol at a temperature of 150 °C. However, only 30 % of phenol was found to react with wood components. Furthermore, the findings associated with the enthalpy activation showed that the wood phenolysis have a dominant endothermic nature of the reaction.

Lee and Ohkita (2003) showed that wood can be rapidly liquefied in the phenol at supercritical temperatures. Under these conditions, over 90 % of wood was liquefied for 30 seconds, and the properties of the product were similar to those obtained by conventional liquefaction methods. Furthermore, Honglu and Tiejun (2006) used ionic liquids based on the imidazole as reagents for wood liquefaction, and found that by using this method quick and complete liquefaction at 120 °C for 25 min without an acidic catalyst can be achieved.

2.2 Wood liquefaction with polyhydric alcohols

Unlike liquefaction with phenol, the polysaccharides liquefaction mechanism with polyhydric alcohols occurs by alcoholise of glucosidal degradation. When using these polyhydric alcohols, anomer hydroxyl groups reduction end groups or the one from liberated glucose are protonised or alcoholised, so we get the same glycoside as in alcoholised mentioned before. Also, as in liquefaction with phenol, at the polysaccharides liquefaction in polyhydric alcohols first incurred the corresponding glucosides. Due to decomposition and reaction with the polyol, the liquefaction method converts wood components in reactive molecules (Tišler, 2002; Grbac et al., 2003).

The properties of newly established resins with liquefied wood are dependent not only on the lignocellulosic materials, but also on the size of wood particle. Generally, we can say that average size of wood particle (about 120 mesh) give composites of better performance and properties than those from smaller or bigger particles (Antonović, 2009a).

In previous studies, from the polyhydric alcohols for wood liquefaction most commonly used are ethylene glycol (EG), diethylene glycol (DEG), dipropylene glycol (DPG), polyethylene glycol (PEG-400), glycerol, 1,6-hexandiol and 1,4-buthandiol etc., as well as their mutual mixtures in different ratios. Sulphuric, phenolsulphuric, phosphoric, hydrochloric and oxalic acid were used as catalysts. It should be noted that the use of acid catalysts leads to the re-condensation of already decomposed wood components, which is a negative phenomenon. Various authors combined the liquefaction parameters, making it possible to perform wood liquefaction at temperature up to 350 °C, at normal pressure, and the time interval between 15-180 minutes (Tišler, 2002).

Recently, studies have appeared and promising results regarding the improvement of wood liquefaction procedures in polyhydric alcohols, in terms of reducing the ratio of wood/solvent. Thus, Kobayashi et al. (2005) studied the effect of treating wood with ozone in gaseous or liquid phase on the liquefaction process, and showed that it can be easily liquefied from untreated wood. Obtained liquefied wood had a very high ratio of wood/solvent, and the wood is pre-treated with ozone in the liquid phase. They showed that liquefied wood with a ratio of wood/solvent of 2:1 has sufficient fluidity to be activated as a starting material for chemical products, and it is possible to increase the content of the final wood products.

Kržan and Kunaver (2006) showed that wood can be effectively liquefied using microwave radiation as a source of heat. This method proved to be a quick way to heat the reaction mixture to temperatures above 250 °C, causing the acceleration of liquefaction process. For example, when only glycol and organic acid anhydrides are used with the addition of phosphoric acid as the catalyst, complete liquefaction can be reached in 20 min. Higher content of liquefied wood are achieved at higher radiant power (300-700 W), longer irradiation time (5-20 min) and higher concentrations of phosphoric acid. Obtained liquefied wood had a complex composition of low molecular compounds, whose chemistry is not studied in detail. Variation of the liquefaction reactants showed that these procedures can use a wide range of reagents (glycol and anhydrides), commonly used in the formulations of resins, adhesives and coatings, without reducing efficiency. In fact, this leaves considerable freedom in designing the chemical structure of liquefied wood components that can be best suit to their end use. Furthermore, the results of using different types of wood species indicate that these liquefaction parameters can be applied to many hardwoods. The method of heating with microwave radiation showed promising application in the rapid development of laboratory experiments.

Generally, the wood liquefaction procedures with polyols are very simple. Their performance is not demanding, they do not use high pressure or very high temperatures, which makes experiments simpler.

3. RESINS MODIFICATION WITH LIQUEFIED WOOD FOR WOOD COMPOSITE MATERIALS

3.1 Particleboards

Liquefied wood-phenol-formaldehyde resins

A survey, in which the wood bark was liquefied with phenol in the presence of sulphuric acid as catalyst, showed that all anatomical parts of wood can be used for liquefaction. After setting a certain density with formaldehyde, a new type of phenol-formaldehyde resin was obtained. Bark wood has replaced up to 33 % of phenol-formaldehyde resin in the mixture. Lee and Liu (2003) were liquefied barks of Taiwan acacia (*Acacia confusa*) and China fir (*Cunninghamia lanceolata*) in the presence of phenol with sulfuric acid (H_2SO_4) and hydrochloric acid (HCl) as catalyst. The properties of resins prepared from liquefied bark and the feasibility of liquefied bark-based resol resins in particleboard manufacturing were investigated. The viscosity and thermosetting property of liquefied bark-based resol resins were affected by the kind of bark species and the catalyst used. Resol resins prepared from bark liquefied with H_2SO_4 as catalyst had higher viscosity, while resins with HCl as catalyst had a higher maximum temperature and height of exothermic peak and a larger quantity of exothermic heat at thermosetting. Particleboard made with A-S adhesive that was prepared from liquefied Taiwan acacia bark with H_2SO_4 as catalyst had the best particleboard properties than those made with other adhesives. For the particleboard made with A-S adhesive, its static bending strength and internal bonding strength would be increased as the hot pressing time extended. The particle board made with hot-pressing temperature of 150°C and hot pressing time of 10 min had the maximum normal and wet static bending strength and internal bonding strength. Its normal static bending strength was 170,8 kg/cm^2 and the particle board showed satisfactory wet static bending strength and internal bonding strength.

Hassan et al. (2009) liquefied southern pine wood in phenol in 30–40:70–60 weight ratios resulted in homogeneous liquefied materials, which were directly used to synthesize phenol–formaldehyde (PF)-type resins. The synthesized resins showed good physical and handling properties: low viscosity, stability for storage and transportation, and resin applicable by a common sprayer. Particleboards bonded with the synthesized resins showed promising physical properties and significantly lower formaldehyde emission values than those bonded with the urea-formaldehyde resin control. One deficiency observed for the synthesized resins was lower internal bond values, which might be overcome the use of a hot-stacking procedure. Overall, the process of wood liquefaction with limited amounts of phenol as a solvent was shown to have the potential of providing practical, low-cost PF-type resins with very low formaldehyde emission potentials.

Lee and Oh (2010) were liquefied *Pinus densiflora* wood flour in the presence of phenol, using sulfuric acid as a catalyst. Liquefaction-modified phenol-formaldehyde (LPF) resins were synthesized as particleboard binder. The physical characteristics of the laboratory-synthesized control PF resin and the LPF resins are described. Laboratory particleboard was made using Korean hybrid poplar (*Populus alba* × *glandulosa*) particles with the control PF resin and LPF resins. The physical strength and dimensional stability of the particleboards were tested according to ASTM D 1037-99 and KS F 3104 standard procedures. Particleboard test results show that the physical and mechanical strength properties differed significantly according to resin type; however, all particleboardss made in this study exceeded the minimum strength requirement of the Korean Standard KS F 3104 for PB type 8,0.

Liquefied wood-urea- and melamine-urea-formaldehyde resins

Antonović (2008) researched the new systems of urea-formaldehyde adhesives modified with liquefied wood for particleboards production. Based on the obtained results, liquefied wood showed that it does not have any polymer or adhesion properties. Regarding that laboratory synthesis of designed liquefied wood-formaldehyde resin (LWF resin) was conducted. Liquefied wood is synthesized with formaldehyde respectively. Due to the polyphenolic properties of lignin in liquefied wood, LWF resin was synthesized analogously to the production of novolac-type of phenol-formaldehyde resin, and was prepared based on the percentage of lignin content in the researched type of wood specie (poplar). The ratio of formaldehyde/phenol was determined in a molar ratio of 0.75/1, in the reactor at 90 °C for 120 min. Prepared LWF resin was used in the modification of urea-formaldehyde resin up to 15 %, and obtained results showed a significant reduction of free formaldehyde emissions, whith maintaining good particleboards physical and mechanical properties.

Antonović et al. (2009a, 2009b) explored the influence of experimental pressing parameters on the compatibility of liquefied wood with urea-formaldehyde resins, the influence on polymer structure and adhesion-cohesion properties of modified urea-formaldehyde adhesives and on the physical-mechanical properties and formaldehyde emission of particleboards. The results showed that in all cases of replacement of urea-formaldehyde resin wood with liquefied wood, emission of formaldehyde in particleboards was significantly reduced.

Furthermore, the same authors researched the properties of particleboards produced with catalytic activity of liquefied wood on urea-formaldehyde resin polymerization, and compared them with particleboards that were produced with commercial type of catalyst, such as ammonium chloride and ammonium sulphate. Before use, liquefied wood was not specially prepared, but the highly acidic nature of its components that enables liquefaction was used for resin polymerization. Results showed that liquefied wood as a catalyst proved to be successful in replacing the classical and commercial types of catalysts. Obtained studies showed that liquefied wood as a catalyst has a positive effect on polymer structure, adhesion-cohesion properties of urea-formaldehyde adhesives, on the physical-mechanical properties and formaldehyde emission of particleboards (Antonović et al., 2010a; Antonović et al., 2010c).

Kunaver et al. (2010a) used glycerol/diethylene glycol (4/1,w/w) as liquefaction solvent to obtain liquefied wood with high hydroxyl group content. A small amount of diethylene glycol in the binary solvent was to reduce the viscosity of the final resin products so that they can meet the application requirement. Liquefaction was conducted at 180°C for 3 h using p-toluenesulfonic acid as the catalyst (3% based on the weight of liquefaction solvent). The resulting liquefied wood was blended with commercial urea–formaldehyde (UF), melamine–formaldehyde (MF), or urea–melamine–formaldehyde (MUF) resins and used for making particleboard. Blending of liquefied wood to the UF, MF, or MUF increased the gel time of the pure resins, and they increased with the increasing loading amount of liquefied wood. Addition of liquefied wood to the MF and MUF resins could reach to 50%, and the particleboard made with these resins could attain satisfactory properties required by the European particleboard standard. The formaldehyde emissions of the panels made from liquefied wood blending resins were all lower than those from pure resins without liquefied wood. The author suggested that the lignin fragments in liquefied wood could be served as a formaldehyde scavenger due to their aromatic structures.

Ćuk et al. (2011) were produced three-layer particleboards using liquefied wood in an adhesive mixture. The influence of two different formaldehyde resins: melamine-formaldehyde and melamine-urea-formaldehyde resin and two various catalysts: ammonium sulfate and ammonium formate on the particleboard properties was investigated. There were also two pressing parameters examined: temperature and time. The following physical and mechanical properties of particleboards were measured: board thickness, density, moisture content, bending strength and modulus of elasticity, internal bonding strength, surface soundness, thickness swelling and formaldehyde content. The results showed that properties of produced particleboards were better when melamine-formaldehyde resin and ammonium formate as a catalyst were used in combination with liquefied wood in the adhesive mixture. Also, mechanical properties were improved as the press time and press temperature increased. The optimal mechanical properties of particleboards made with the utilization of the liquefied wood in the adhesive mixture were achieved at 3 min press time and 180°C press temperature using melamine-formaldehyde resin and 3% of ammonium formate as a catalyst.

Poljanšek et al. (2013) were investigate the effect of liquefied wood (LW) on the cure kinetics and network properties of melamine-urea-formaldehyde (MUF) resins by differential scanning calorimetry. The MUF/LW compounds exhibited two distinct cross-linking processes. It can be assumed that there did not appear to be a coreaction of the MUF with the LW. The overall apparent activation energies (E (a)) of the curing reactions were calculated using the Kissinger equation. An nth-order kinetic model was used to describe the cross-linking of MUF/LW compounds, of various compositions, cured at different heating rates. The E (a) values for the cross-linking process of the MUF/LW compounds predominantly tended to be approximately 80 and 71 kJ mol(-1) for MUF and LW, respectively. The apparent reaction orders of the MUF cross-linking process of the MUF/LW compounds were in the range 1-2, whereas the n values of the LW were approximately unity or less, which hints to there being a more complex mechanism of this process.

3.2. Plywoods

Liquefied wood-phenol-formaldehyde resins

Santana et al. (1995) were liquified tannin as an alternative to phenol, a petroleum-based nonrenewable resource, in phenol-formaldehyde resins which can be developed to support the wood-based panel industry. Tannin from black wattle (Acacia mearnsii) was liquefied with phenol in the presence of acid catalyst. In this study, tannin was replaced 33% of the phenol in the preparation of resol-type plywood adhesives. Loblolly pine (*Pinus taeda*) plywood bonded with the liquified tannin resin had strengths and wood failures that were comparable to commercial phenol-formaldehyde adhesives and significantly better than unmodified tannin-formaldehyde adhesives when used to bond Southern Pine under bonding conditions commonly employed with phenol-formaldehyde resins.

Some authors have shown that phenolic adhesives made of five parts of wood and two parts of phenol have the same adhesive properties as well as commercial phenolic adhesives. Gluing of veneer thickness of 1 mm was carried out in the hot-press for 30 seconds at a temperature of 120-130°C for plywood production. Pressing temperature was almost 15°C lower than the temperature required for commercial phenolic adhesives (Tišler, 2002).

Furthermore, Lee et al. (2011) were liquefied wood of Japanese cedar (*Cryptomeria japonica*) in phenol with H_2SO_4 or HCl as catalysts and used as raw materials to prepare phenol-formaldehyde (PF) resins. The curing behavior and adhesion properties of resins prepared were investigated. Wood liquefied with H_2SO_4 as a catalyst had better liquefaction effect than that with HCl; however, the reaction of resin synthesis was hard to control due to its quickly increasing viscosity. Differential scanning calorimetry analysis shows that PF resins prepared from HCl-catalyzed liquefied wood had higher reactivity than those of H_2SO_4-catalyzed wood. These PF resins were employed for manufacturing three-layer plywood. The wet bonding strength of plywood prepared with resins from HCl-catalyzed liquefied wood exceeded 0,7 MPa and fulfilled the requirement of the CNS 1349 standard.

Lee et al. (2012) were liquefied alkaline lignin (AL), dealkaline lignin (DAL), and lignin sulfonate (SL) in phenol with sulfuric acid (H_2SO_4) or hydrochloric acid (HCl) as the catalyst. The phenol-liquefied lignins were used as raw materials to prepare resol-type phenol-formaldehyde resins (PF) by reacting with formalin under alkaline conditions. The results show that phenol-liquefied lignin-based PF resins had shorter gel time at 135°C and had lower exothermic peak temperature during DSC heat-scanning than that of normal PF resin. The thermo-degradation of cured phenol-liquefied lignin-based PF resins was divided into four temperature regions, similar to the normal PF resin. When phenol-liquefied lignin-based PF resins were used for manufacturing plywood, most of them had the dry, warm water soaked, and repetitive boiling water soaked bonding strength fitting in the request of CNS 1349 standard for Type 1 plywood ().

Liquefied wood-isocyanate resins

Tohmura et al. (2005) were liquefied wood were blended with PMDI and used water based polyisocyanate adhesives (API). They were liquefied Sugi (*Criptmeria Japonica*) wood meal with a mixture of poly (ethylene glycol) 400 and glycerol (7/3, w/w) in the presence of a sulfuric acid catalyst. Liquefaction was carried with the following conditions: solvent/wood ratio 3/1, temperature 150°C, time 1,5–5h. An equivalent amount of 40% NaOH was added to neutralize the acid catalyst after liquefaction. The resulting liquefaction products were used directly to prepare isocyanate adhesives via mixing with polymeric diphenylmethane diisocyanate without the removal of the residue. Liquefied wood isocyanate (LWI) resins were prepared by blending 100 parts of liquefied wood with 158 parts of PMDI. The total solid content of the LWI was more than 90% and higher than that of a commercial API at about 66%. The LWI resin was applied to plywood adhesives, and the properties of the liquefaction products and the performances of bonded plywood were tested. Three layer plywood panels were made to evaluate the properties of the LWI resin. LWI resin was spread with 166 g/m^2 on both sides of the core veneer. The results showed that the residue content decreased and the hydroxyl value increased as the reaction time increased. The viscosity and weight-average molecular weight significantly changed with the reaction time. Both the dry and wet shear strengths of the panels were than the commercial API resin and decreased with longer liquefaction time. Since the LWI had relatively low viscosity, the lower strength could be attributed to the over penetration of the LWI resin through the wood surface. All the dry test results of the shear strength met the Japanese Agricultural Standard (JAS) criteria for plywood. After a cyclic steaming treatment, however, only the plywood bonding with adhesives from the liquefied wood with a reaction time of 1,5h satisfied the JAS criteria. The wood failure was very low. The emissions of formaldehyde and acetaldehyde were extremely low. They concluded that liquefied wood-based isocyanate adhesives have the potential to become ideal wood adhesives because of their bond durability, safety, and recyclability.

Kishi et al. (2006) were synthesized wood-based epoxy resins from resorcinol-liquefied wood. Wood was first liquefied in the presence of resorcinol with or without a sulfuric acid catalyst at high temperature. Because of the hydroxyl groups, the resorcinol-liquefied wood was considered as a precursor for synthesizing wood-based epoxy resin. Namely, the phenolic OH groups of the liquefied wood reacted with epichlorohydrin under alkali condition. By the glycidyl etherification, epoxy functionality was introduced to the liquefied wood. The epoxy functionality of the resins was controlled by the concentration of phenolic OH groups in the liquefied wood, which would be a dominant factor for crosslink density and properties of the cured epoxy resins. The flexural strength (150-180 MPa) and the modulus of elasticity (3.2 GPa) of the highly crosslinked wood-based epoxy resin were equivalent to those of the commercially available epoxy resin, diglycidyl ether of bisphenol A (DGEBA). Also, the shear adhesive strength of the wood-based epoxy resin was higher than that of DGEBA when plywood was used as the adhesive substrates. The mechanical and adhesive properties suggested that the wood-based epoxy resins would be well suited for matrix resins of natural plant-fiber reinforced composites.

3.3 Solid wood panels

Ugovšek and Šernek (2013) were liquefied wood at 180°C using ethylene glycol as the solvent and sulphuric acid as a catalyst. In the first part of research, liquefied wood with different pH values was used for the bonding of solid wood at 200°C for 15 min. In the second part, liquefied wood with an optimal pH value was used for bonding at different press temperatures for 15 min. In the third part, the minimum pressing time at the optimal pH value and at the optimal press temperature was determined. Unmodified liquefied wood with a negative pH value, a press temperature of 180°C, and a pressing time of 12 min was determined to be optimal (based on highest shear strength) for the bonding of 5 mm thick wood lamellas with the LW used in this study. At these conditions bonds exhibited shear strength of around 7 N/mm^2 which was too low to attain standard requirements.

Despite this, high wood failure (100%) was observed as a consequence of low pH value and high press temperature which caused damage of the part of beech lamellas where liquefied wood was applied.

4. CONCLUSION

This overview showed validity for the researches of liquefied wood application synthetic resins modification and polymerization in novel types of wood composites. When talking about it's potential use in the wood industry, attention must be focused on development of different types of resins (phenol- and urea-formaldehyde, polyurethane, epoxy, resorcine or isocyanate resins) for wood composite materials production (wood-based panels). Based on previous researches presented in this paper, liquefied wood showed potential in resins designed for the wood composite materials production, as partial or complete replacement for synthetic resins. Finally, the present studies indicated unimaginable possibilities of scientific research and development aimed at improving different types of resins derived from liquefied wood, and opened new challenges in the researches of natural, environmentally impeccable materials with unlimited raw resources.

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THE SITUATION WITH EXPORT AND IMPORT OF SAWN WOOD IN THE REPUBLIC OF MACEDONIA

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ABSTRACT

From the total production of sawn wood in the Republic of Macedonia, ¾ are produced from non - coniferous trees and only ¼ is produced from coniferous trees. Sawn wood foreign trade is conditioned by the situation mentioned above. The Republic of Macedonia is importer of sawn wood from coniferous trees and exporter of sawn wood from non coniferous trees. This paper analyses the situation with export and import, their structure and their regional focus, as well as defines the strategic partner countries.

Key words: conditions, export, import, sawn wood, non – coniferous, coniferous, regional strategy

1. INTRODUCTION

International trade, i.e. export and import of products is an imperative for every country, especially for the developing countries.

For the Republic of Macedonia there is no other alternative but increasing export and involvement of our country in international trade. Despite this, both scope and role of export and import of sawn wood in Macedonia do not play a significant role in the state's total international trade. Sawn wood is not one of the products which are most exported on a state level, but it is the most valuable product when talking about exporting wood industry products. On the other hand, the enormous increase in the number of companies involved in wood industry has led to an increase of the import of sawn wood.

2. SUBJECT AND OBJECTIVE OF THE RESEARCH

The subject of this research is export-import difference of sawn wood in Macedonia. Subject of the analysis were total export and import, contribution of separate types of sawn wood and their dynamics, export-import difference and the strategic partners for export and import of sawn wood.The research is based on data from the documents available at the State Statistical Office according to SMTK, audit 3, based on the profit realized from export and import, expressed in US dollars.

The goal of this research is:

- to comprehend the tendencies of export-import of sawn wood and export-import difference,
- to ascertain the strategic partners in trade with sawn wood, and
- to determine R. of Macedonia's position in export-import of sawn wood, as well as to establish ways and opportunities of improving it.

3. EXPORT - IMORT OF SAWN WOOD

Export - import of sawn wood in the R. of Macedonia was analyzed for the period from 2005 till 2010. The data for export - import of sawn wood from coniferous and non-coniferous trees was analyzed through the value realized, expressed in US dollars.

The first information that is obvious from the data in table No. 1 for export of sawn wood is the low share of sawn wood from conifers.

In some years of the period analyzed, in 2005, 2006 and 2009, there was no export at all. In the remaining three years (2007, 2008 and 2010) that export was extremely low, therefore marginal. It varied from 4 % in 2008, 5% in 2007 and 8% in 2010.

Table 1. Export and import of sawn wood

- in 000 US dollars

	Sawn wood from non-coniferous			Sawn wood from coniferous			Total amount of sawn wood		
	Export	Import	Export-import difference	Export	Import	Export-import difference	Export	Import	Export-import difference
1	2	3	4	2	3	4	2	3	4
2005	3116	958	2158		10865	-10865	3116	11823	-8707
2006	2457	483	1974	/	10327	-10327	2457	10810	-8353
2007	4811	960	3851	273	9693	-9420	5084	10653	-5569
2008	4233	1184	3049	173	11794	-11621	4408	12978	-8572
2009	3059	1555	1504	/	12738	-12738	3059	14293	-11234
2010	1964	1176	788	158	9022	-8864	2122	10189	-8067
average	3273	1053		101	10740		3374	11793	
PGS	-8,82	4,18			-3,65		-7,4	-2,93	

Source: State Statistical Office

The export of sawn wood in the period analyzed was not the same, it varied from year to year. The highest export of sawn wood from non-coniferous was made in 2007 amounting 4.811.000 US dollars, and the lowest in 2010 amounting 1.964.000 US dollars. Based on the data from Figure 1 we can see that the export of sawn wood in the period analyzed had a falling tendency starting from 2007 on.

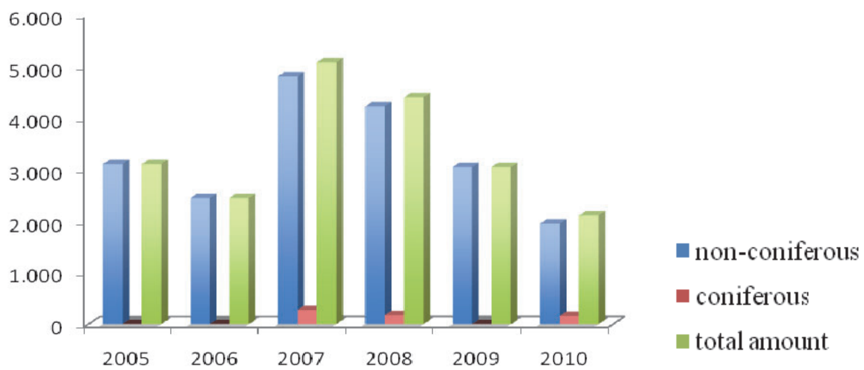

Figure 1. *Export of sawn wood*

Based on this data we can see that in the period analyzed the Republic of Macedonia exported mainly sawn wood from non-coniferous trees. This export of sawn wood from non-coniferous trees had a declining tendency. From total export of sawn wood in the period analyzed, 97% came from sawn wood from non-coniferous trees and only 3% came from conifers.

During the period analyzed, 2005 -2010, import of sawn wood showed a totally different tendency compared to the export (Table 1). When importing comes to question, the highest import came from sawn wood from coniferous trees, unlike their export which was almost non existent.

The highest import of sawn wood from coniferous trees was recorded in 2009 with 12.738.000 US dollars, and the lowest in 2010 with 9.022.000 US dollars. The share of import of sawn wood from coniferous trees in the total import of sawn wood amounted on average 91% (Figure 2).

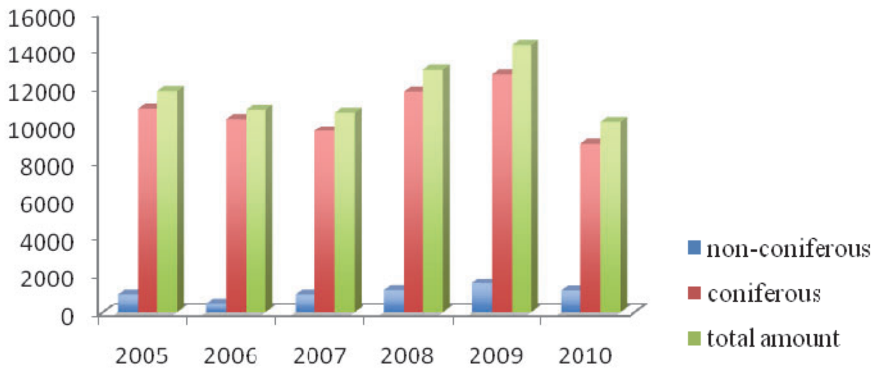

Figure 2. *Import of sawn wood*

As already said, the import of sawn wood from non-coniferous trees was fairly low. In the period analyzed, although there was a rising tendency, it ranged between low percentages, from 5% and 12% in 2006 and 2010 respectively. In the total import of sawn wood, the share of sawn wood from non-coniferous trees amounted only 9%.

On the basis of the data for total export and import of sawn wood and separately by types of trees, the Figure 3 below was drawn out.

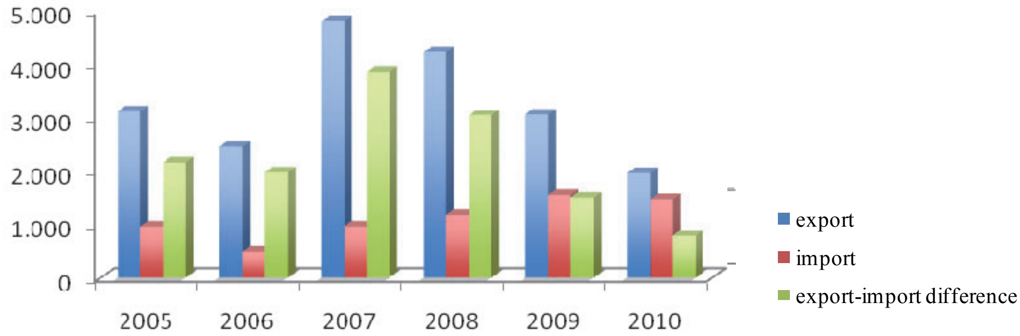

Figure 3. *Export-import difference of sawn wood from non-coniferous trees*

Figure 3 shows that throughout the period analyzed the difference between export and import of sawn wood from non-coniferous trees was positive. According to this data, during the period analyzed the Republic of Macedonia had higher export than import of sawn wood from non-coniferous trees. However, it is noticeable that that positive difference between export and import was declining in the last few years of the period analyzed.

Sawn wood from coniferous trees, according to the analyses and the data from Figure 4 shows an opposite tendency compared to sawn wood from non-coniferous trees. With the conifers, the export-import difference was negative for all the years from the period analyzed, having in mind that during the three-year period, there was no export whatsoever of sawn wood from coniferous trees.

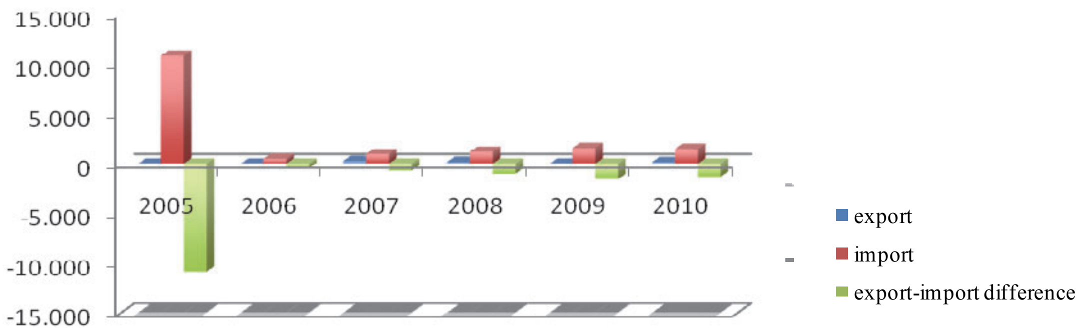

Figure 4. *Export-import difference of sawn wood from coniferous trees*

If we analyze now the total export-import difference of sawn wood in the Republic of Macedonia, we will come to the conclusion that it is negative.

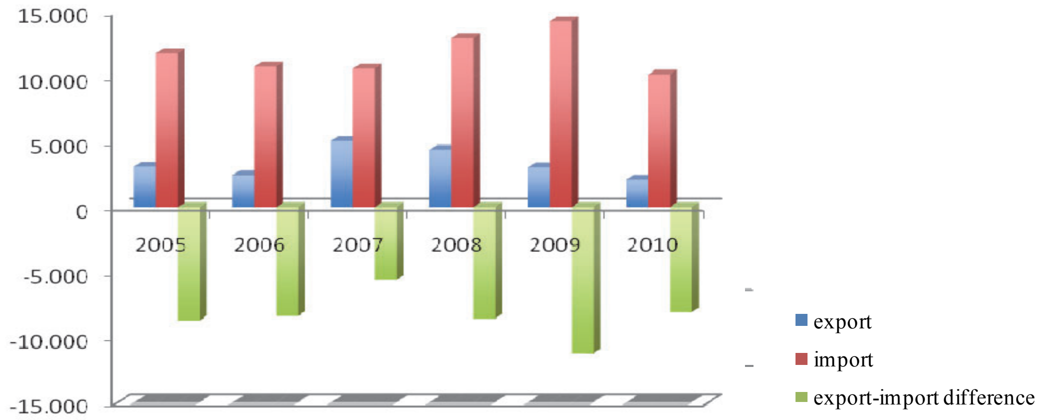

Figure 5. *Total export-import difference of sawn wood*

On the basis of the data, it is clear that the negative trend during the last few years of the period analyzed had been rising, despite the fact that the export-import difference of sawn wood from non-coniferous trees was positive. Yet, it did not affect the overall condition, because sawn wood from non-coniferous trees had a small share in the total export-import of sawn wood.

3.1 Regional orientation of international export-import of sawn wood

Regional orientation is presented for separate types of sawn wood, the type originating from coniferous and from non-coniferous trees.

The percentage share of separate countries in export and import of sawn wood was calculated on the grounds of the value realized, expressed in US dollars.

Table 2 gives the regional orientation of export of sawn wood from non-coniferous trees As we can see from the analyses of international export-import of sawn wood, we already know that during the period analyzed the Republic of Macedonia exported only sawn wood from non-coniferous trees. Accordingly, the analysis of regional orientation was made only for export of sawn wood from non-coniferous trees.

Table 2. *Export of sawn wood from non-coniferous trees*
- in % from the value realized

Country	2005	2006	2007	2008	2009	2010
Greece	31	30	21	32	26	25
Slovenia	21	20	/	/	/	/
Italy	17	30	27	20	24	33
Germany	/	/	21	26	30	27
Others	31	20	31	22	20	15
Total	100	100	100	100	100	100

Source: State Statistical Office

According to the data from table 2, we can see that for the Republic of Macedonia's export of sawn wood from non-coniferous trees, there were 3 countries that were significant: Greece, Italy and Germany. In 2005 and 2006, the export of sawn wood from non-coniferous trees was carried out from the Republic of Slovenia, but from 2007 to 2010, Germany took Slovenia's place, with a share of 25%

of Macedonia's export there of sawn wood from non-coniferous trees. According to data from table 2, we could conclude that all the three countries, Greece, Italy and Germany, in the period from 2007 to 2010 had about the same share of percentage in the export of sawn wood. Their total share amounted to almost 80% from the total export, and only 20% was in other countries.

In 2010 sawn wood from non-coniferous trees was most exported to Italy 33%, to Greece 25%, to Germany 22% and the rest of 20% to other countries.

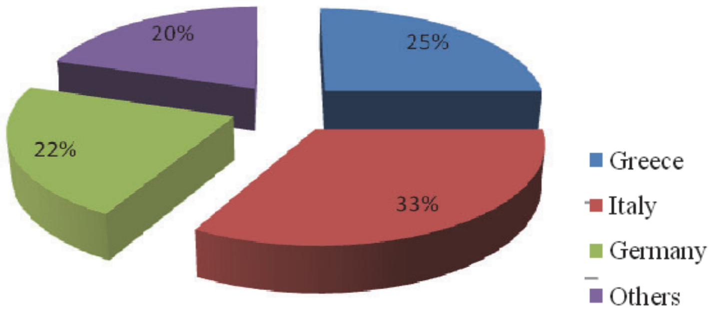

Figure 6. *Structure of export of sawn wood from non-coniferous trees*

As per the analyses for the import of sawn wood, we already saw that 91% of the import came from sawn wood from coniferous trees and only 9% came from non-coniferous trees. For that reason, we will discuss first the regional orientation of import of sawn wood from coniferous trees. Regional orientation of import of sawn wood from non-coniferous trees will be analyzed too, but its significance is very small, as already stated.

Table 3. *Import of sawn wood from coniferous trees*
- in % from the value realized

Country	2005	2006	2007	2008	2009	2010
Bulgaria	60	45	32	21	49	59
Bosnia and Herzegovina	15	28	44	35	13	18
Slovenia	/	13	17	16	/	/
Romania	12	/	/	/	/	/
Austria	/	/	/	/	18	9
Other countries	15	14	7	28	20	14
Total	100	100	100	100	100	100

Source: State Statistical Office

Table 3 presents the data regarding the percentage share of each country separately with respect to import of sawn wood from coniferous trees.

We can see from the data that the import of sawn wood from coniferous trees in the Republic of Macedonia was carried out from a small number of countries. Thus, in 2006, 2007 and 2008, main countries for import of sawn wood from coniferous trees were Bulgaria, Bosnia and Herzegovina and Slovenia. It is an important fact that in 2005, 60% of the total value of sawn wood from coniferous trees was imported from Bulgaria, but its share was gradually declining and in 2008 its share amounted 21%. In the last 2 analyzed years however, Bulgaria's share started to rise again and in 2010 it amounted 59%.

The import of sawn wood from coniferous trees from Bosnia and Herzegovina varied depending on the year, but there was import throughout the whole period. The highest import was in 2007 when its share was 40% from the total import, and the lowest was in 2009, with only 13%.

Slovenia was an exporter of sawn wood from coniferous trees to the Republic of Macedonia only for a period of three years (2006, 2007, 2008) with share of 13-17%. During the last years analyzed, Austria took Slovenia's place as a country from which sawn wood from coniferous trees was imported, but its share was very low, 18% and 9% in 2009 and 2010 respectively.

According to data from table 3, we can see that main countries with which export-import of sawn wood from coniferous trees in 2010 was made were: Bulgaria with a share of 59%, Bosnia and Herzegovina with a share of 18% and Austria with a share of 9%, i.e. these three countries participated with 86% in the total import of sawn wood from conifers, and the other countries participated with a share of 14%.

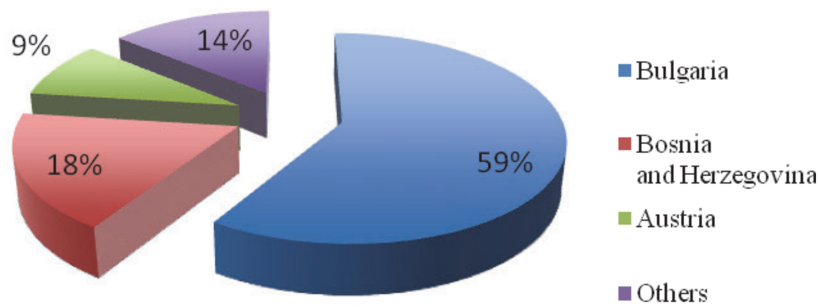

Figure 7. *Structure of the import of sawn wood from coniferous trees*

In the end, we can say that regional orientation of international trade with sawn wood from coniferous trees in the Republic of Macedonia, was limited to a small number of countries, primarily neighboring countries, countries from former Yugoslavia, or some European countries such as Italy, Austria and Germany.

4. CONCLUSIONS

Based on the analyses of the situation with export and import of sawn wood from the Republic of Macedonia, for the period from 2005 till 2010, the following conclusions were made.

1. The Republic of Macedonia exported sawn wood from non-coniferous, and imported sawn wood from coniferous trees.
2. The value of total realized export and import, and separately by types of sawn wood (from non-coniferous and coniferous trees) showed a negative tendency, i.e. a declining trend.
3. Total sawn wood and sawn wood from coniferous trees had a negative export-import difference, and sawn wood from non-coniferous had a positive one. But the share of sawn wood from non-coniferous trees in export-import was so low that it did not affect the overall trading activities.
4. Macedonia's strategic partners for export of sawn wood were Greece, Italy and Germany, and Bulgaria held the leading position in import, whereas Bosnia and Herzegovina came second and Austria third.

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EXAMPLES OF USING MECHANICAL TESTS OF FURNITURE FOR DESIGNING PRODUCTS MARKETED IN POLAND

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ABSTRACT

Poland is amongst the major furniture manufacturers in Europe: in 2010-2011 Poland was sixth in furniture production, and third in furniture export out of all European countries. The author compares manufacturing dynamics in the furniture sector and the amount of product subjected to technical tests. The procedure of laboratory tests of furniture as well as testing sites shall be described. Moreover, the legal basis of the tests shall be clarified as well, i.e. ordinances, acts and EN standards. Test areas shall be specified, that is strength, stability, functional dimensions and furniture structure safety. Furniture structure shall be discussed, i.e. function-wise classification, i.e. storage furniture, lying furniture, seating furniture, as well as tables and desks. Based on the furniture tested, the issue of mattress durability and firmness testing including factors that determine mattress quality, i.e. type of foam , springs, cover, fabric layers, shall all be discussed.

Key words: Furniture, furniture tests, furniture strength, furniture safety, EN standards concerning furniture tests

Poland is amongst the major furniture manufacturers in Europe: in 2010-2011 Poland was sixth in furniture production, and third in furniture export out of all European countries. The quantitative indicators related to manufacturing should be accompanied by the consciousness that the safety of furniture structure solutions has been guaranteed.

Furniture safety

Generally speaking, a safe piece of furniture is a product that in normal usage conditions does not pose any risk to its user. The factors influencing the safety of use are examined in three areas according to the diagram below (Figure 1):The factors related to dimensions and durability shall be discussed in the next part based on selected examples of furniture structures where such factors are known to be found.

Functional dimensions

Functional dimensions are the essential safety factors of the structure of children's cots. Because these cots are used by infants and toddlers, the frame structures are subjected to, among others, checks of distances, gaps, diameters, depths and other dimensions of individual elements.

Form and shape

An appropriate form and shape are also crucial for the safety of children's cots, because the edges must be rounded according to the standard in order to avoid edges that are sharp or unpleasant to the touch. The decorative elements of cot rims should constitute be the so-called grappling spots classified by standards as hazardous (Figure 2).

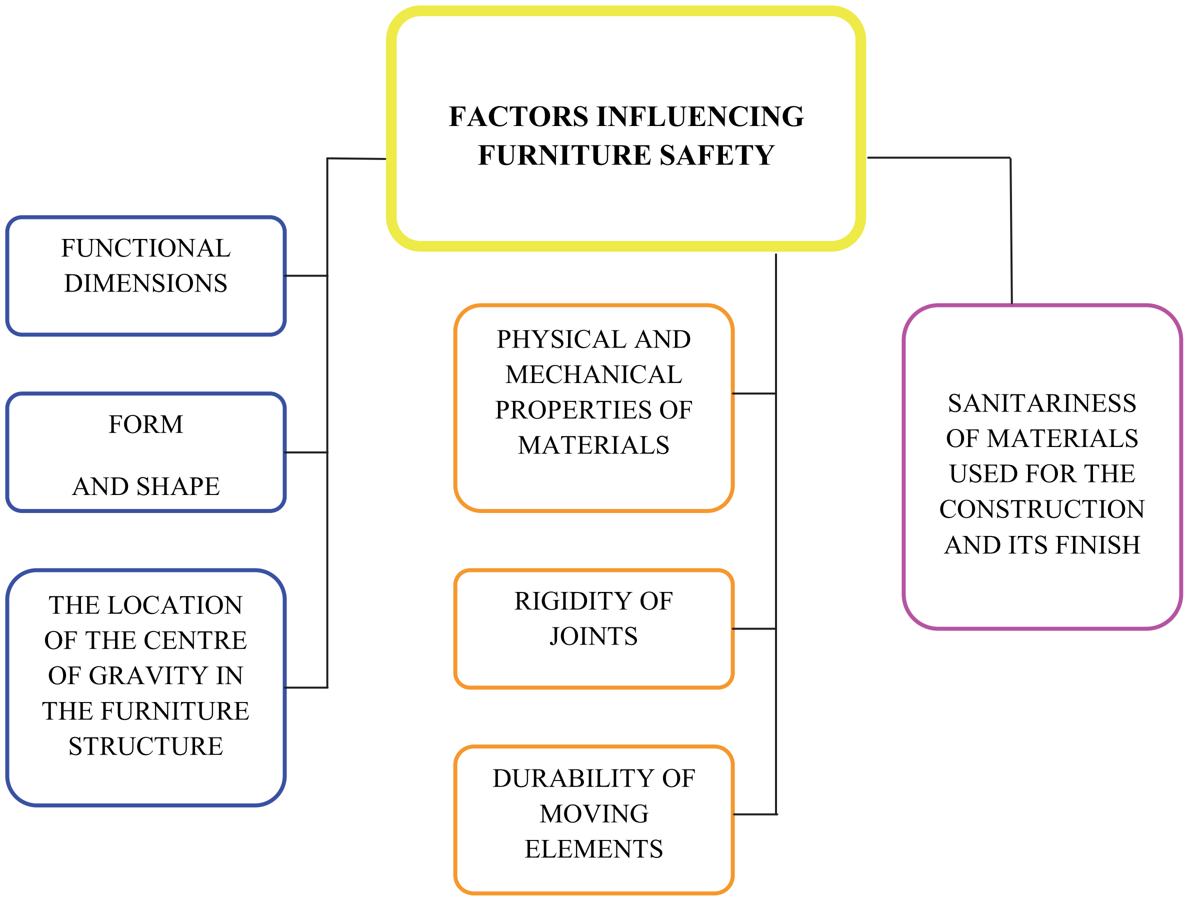

Figure 1. *Division of factors influencing furniture safety: factors enclosed in blue frames are related to furniture shape and dimensions; physical and mechanical properties, and materials including their durability and reliability belong to the orange frame group; the sanitariness of materials and finishes related to chemical compounds present in the furniture product is enclosed in the pink frame.*

Figure 1a-e. *Measurements of children's cot construction elements according to EN 716-1,-2.*

The contour line of elements for direct contact with the user should be rounded and should not cause body parts to become stuck, pinched and so on (Figure 3).

The shape of parts blocking the moving elements, e.g. in convertible designs, should be effective.

Figure 2. *Inspection of edges and grappling elements according to EN 716-1,-2.*

Figure 3. *A decorative cut out in the face element of the drawer replaces the handle; unrounded edges decrease comfort of use and constitute a dangerous spot while closing.*

Physical and mechanical properties of materials

The selection of material according to the function of a piece of furniture and related usage loads is an essential element during the design stage. This especially applies to synthetic plastic polymers which are used for producing thin-walled profiles of construction components, such as: armrests, seats and backrests. Office work chair durability tests according to EN 1335-3 enable finding out whether the type of plastic used has sufficient strength (Figure 4).

Joint rigidity in the furniture structure

The rigidity of furniture structures, especially cabinet furniture, depends on the rigidity of joints. These joints can have various degrees of rigidity depending on the module of linear and shape elasticity of the joining element and joined elements

Figure 4. *Testing office work chair armrests for fatigue load strength; The effect of damage: breaking off of the seat base which the armrest is mounted to; the material used was found to be too weak.*

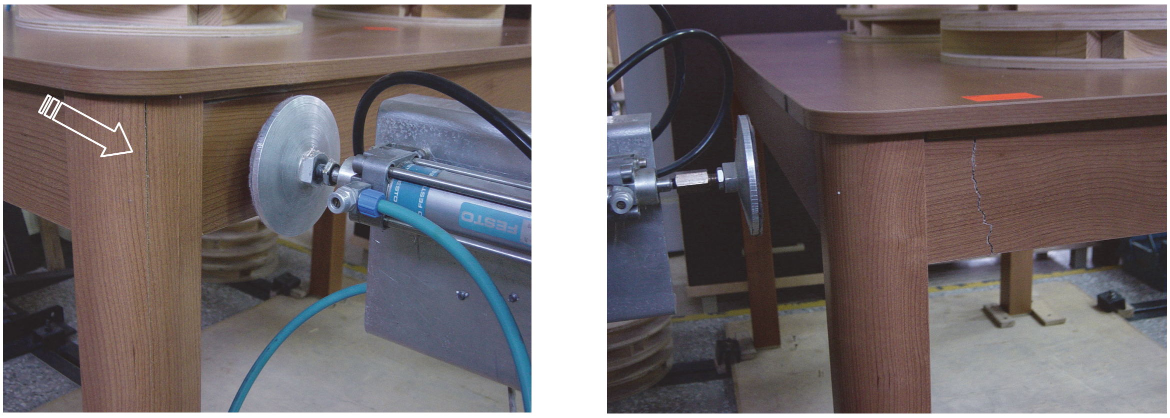

Figure 5. *The material used for the construction (medium-density fibreboard table legs, 16 mm particle board aprons) turned out too weak during table load tests according to EN 1730, which resulted in cracks of marked elements.*

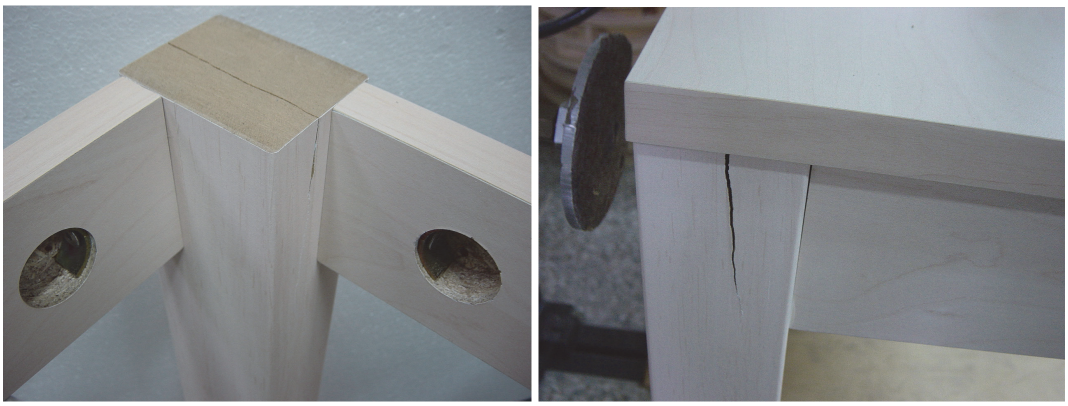

Figure 6. *Table base elements following fatigue tests: a crack at the top of the table leg shows that the material used is weaker than the connection of the leg with the aprons.*

The procedure of transformation of the rigid joint into the semi-rigid joint can be explained as follows. A furniture joint is a set of elements made of various materials because, usually, metal elements are used for joining wood-based elements of lower density, linear and form rigidity modules, characterised by the log volume. When the force is applied to the joint, indentations can be formed, and, subsequently, at first, a little play can be seen, it gradually increases, which, in the end, causes the joint to lose its rigidity (fig. 7,8).

Figure 7. *An example of joints in the table base: the first solution is an example of a semi-rigid joint, because the density and the linear elasticity of materials, and the clamping force of the connecting element ensure limited rigidity to the table construction; the second solution: a support frame base of the table which is partly dismountable and welded ensures considerable rigidity to the joint.*

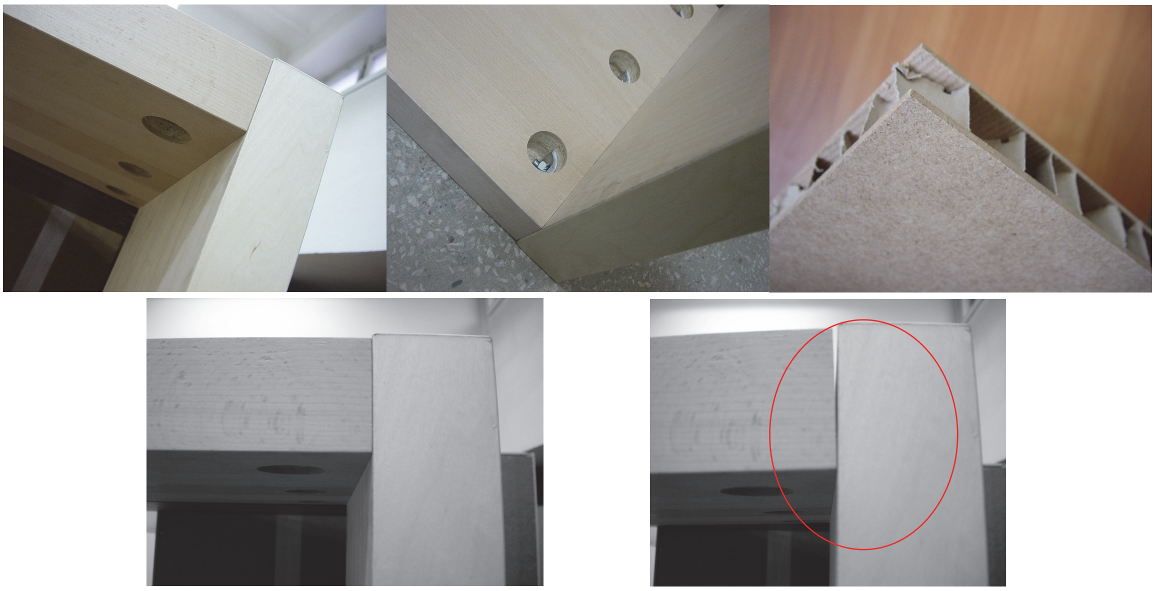

Figure 8. *Angular joint of a table made of cellular wood panel: 1. before the test, 2. after the fatigue test according to EN 1730, visible loosening causing a loss of rigidity of the connection and, as a result, of the entire structure.*

Multi-purpose furniture safety requirements

One of the causes of the trend for designing multi-purpose furniture is the buyers' demand. 9). Convertible (combined) multi-purpose pieces of furniture are intended for more economic use of the living space. This type of furniture is used by children, and increasingly frequently they are produced in a version enabling converting them and changing their function as the child grows. Such a group of furniture must meet strength and durability requirements of conventional furniture (storage furniture, frame furniture, tables, chairs, armchairs, sofas, beds, etc.) imposed by the existing standards and testing procedures. Strength tests of multi-purpose furniture consist in isolating individual construction groups according to furniture types described in the standardised testing procedures. If a piece of furniture has: a cabinet, shelves, top, support frame, then individual isolated construction groups should be assigned appropriate strength test standards. e.g. EN 14749 + EN 1730 + EN 747-1,-2.

Figure 9. *Examples of multi-purpose furniture.*

Summary

The validation based on laboratory measurements of essential parameters of a product is a highly useful expertise because it confirms the safety of the product, compliance of its manufacturing with technical and standard requirements, and it also constitutes a type of warranty in terms of usage durability. Is it necessary to validate and certify a product that has been as highly perfected in terms of construction and production technology as a piece of furniture? In the last couple of years we have seen a systematic growth of industrial production in our country. The industrial production growth differs in various branches, however the furniture industry has been included in the "high opportunity area". Furniture companies have achieved good results and their market perspectives enable them to be placed among the top companies. Furniture production belongs to the sector with high growth dynamics, which includes both large companies with foreign capital and small production plants which all produce the entire range of furniture types. It should be unacceptable to enable selling furniture whose stability and durability are unsatisfactory, as this would introduce some risk, because, e.g. as a result of the lack of stability, the furniture may fall over exposing the user to the risk at work.

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COMPARATIVE ANALYSIS OF STIFFNESS COEFFICIENTS UNDER BENDING TEST OF END AND T-SHAPE CORNER JOINTS OF FRAME STRUCTURAL ELEMENTS WITH CROSS SECTION OF 50 x 30 mm MADE OF SWEET CHESTNUT WOOD

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ABSTRACT

The present study involves a comparative analysis of experimentally established stiffness coefficients under compression bending test of some of the most frequently used end and T-shape corner joints of frame structural elements with cross section of 50 x 30 mm, made of sweet chestnut solid wood. It was established that, first, the type of the joints has a significant influence on their stiffness, and, second, the T-shape corner joints have on average about 11 % greater coefficient of stiffness than the end corner joints.

It is recommended that the comparative data of stiffness coefficients of the tested corner joints is taken into consideration when designers and engineers have to choose the type of joints in the chair constructions.

Key words: end and T-shape corner joints, structural elements, stiffness coefficients, compression bending test, chair constructions, sweet chestnut solid wood.

1. INTRODUCTION

The present study is an extension of the previous two publications (Kyuchukov *at al.* 2011[a], Kyuchukov *at al.* 2012[a]) on the stiffness characteristics of the corner joints of frame structural elements made of sweet chestnut solid wood with rectangular cross section with dimensions of 50 x 30 mm. The type of the tested corner joints of the frame structural elements are shown on Figure 1 and Figure 2. The parameters of the samples correspond to the requirements of BDS 5527-73. The parameters of the samples and the schemes of the compression bending loading are shown on Figure 3. The glued corner joints were manufactured in compliance with the requirement of tightness from 0,05 mm to 0,15 mm. The results obtained from the tests were processed using the variation statistics methods.

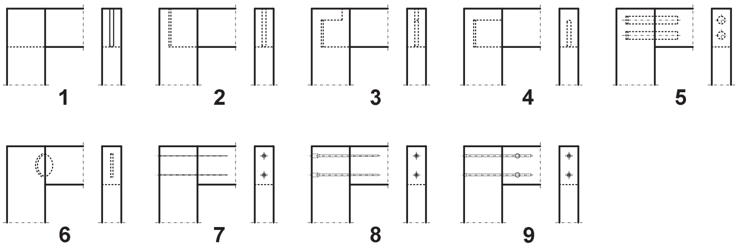

Figure 1. *End corner joints of structural elements made of sweet chestnut solid wood:*

Glued corner joints: **1** – open mortise and tenon joint; **2** – half-open mortise and tenon joint; **3** – haunched mortise and tenon joint; **4** – mortise and tenon joint; **5** – joint with two dowels ϕ 10 mm; **6** – joint with wooden "Lamello plates".
Dismountable corner joints: **7** – joint with two countersunk screws for wood; **8** – joint with two one-piece connectors "Confirmat"; **9** – joint with two connectors with screw and cross dowel.

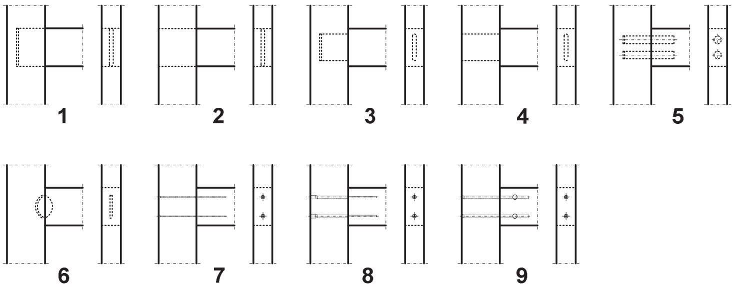

Figure 2. ***T****-shape corner joints of structural elements made of sweet chestnut solid wood:*
Glued corner joints: **1** – stub mortise and tenon, type **A**; **2** – through mortise and tenon type **A**; **3** – stub mortise and tenon, type **B**; **4** – through mortise and tenon with shoulders, type **B**; **5** – joint with two dowels ϕ 10 mm; **6** – joint with wooden "Lamello plates".
Dismountable corner joints: **7** – joint with two countersunk screws for wood; **8** – joint with two one-piece connectors "Confirmat"; **9** – joint with two connectors with screw and cross dowel.

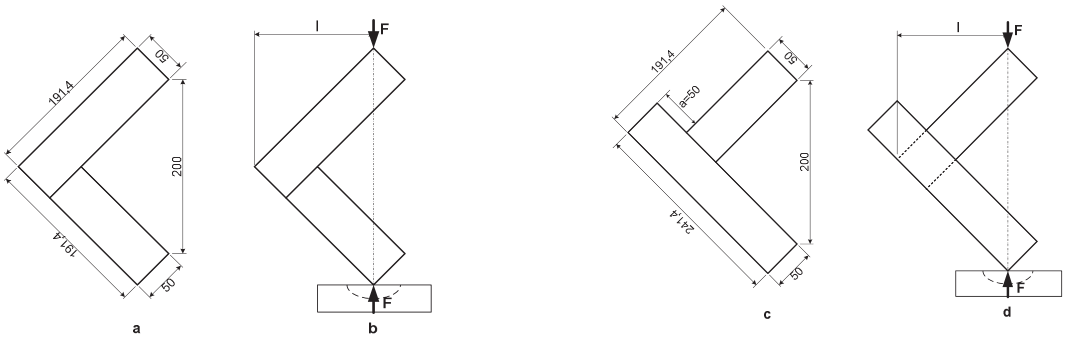

Figure 3. *Dimensions and testing schemes of the samples under compression bending load:*
a *and* ***b*** *– end corner joints;* ***c*** *and* ***d*** *–* ***T****-shape corner joints.*

2. COMPARATIVE ANALYSIS OF THE STIFFNESS COEFFICIENTS OF THE TESTED CORNER JOINTS

Comparative data of the stiffness coefficients of the tested corner joints is shown in Table 1 and on Figure 4.

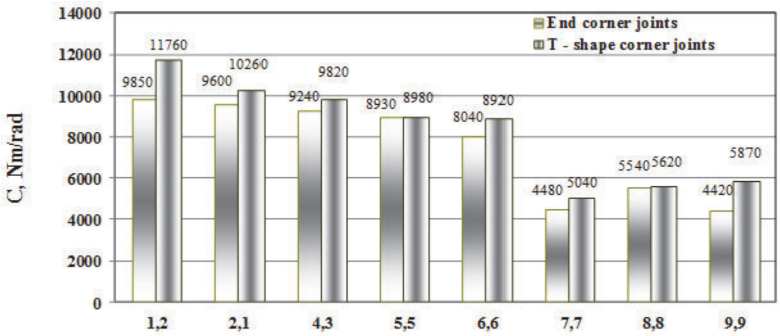

Figure 4. *Comparative data of the stiffness coefficients of the comparable end and* ***T****-shape corner joints of structural elements with cross section of 50 x 30 mm made of sweet chestnut solid wood according to Table 1*

***Table 1.** Comparative data of the stiffness coefficients of the end and T-shape corner joints of structural elements with cross section 50 x 30 mm made of sweet chestnut solid wood*

End corner joints		Comparable T-shape to end corner joints		Ratio c_2/c_1
Type of the joints (according to Fig. 1)	**Stiffness coefficient c_1, N.m/rad**	**Type of the joints (according to Fig. 2)**	**Stiffness coefficient c_2, N.m/rad**	
Glued corner joints		**Glued corner joints**		
1. Open mortise and tenon joint	9 850	2. Through mortise and tenon joint, type A	11 760	1,19
2. Half-open mortise and tenon joint	9 600	1. Stub mortise and tenon joint, type A	10 260	1,07
4. Mortise and tenon joint	9 240	3. Stub mortise and tenon joint, type B	9 820	1,06
5. Joint with two dowels ϕ 10 mm	8 930	5. Joint with two dowels ϕ 10 mm	8 980	1,01
6. Joint with wooden "Lamello plates"	8 040	6. Joint with wooden "Lamello plates"	8 920	1,11
Dismountable corner joints		**Dismountable corner joints**		
7. Joint with two counter-sunk screws for wood	4 480	7. Joint with two counter-sunk screws for wood	5 040	1,12
8. Joint with two one-piece connectors "Confirmat"	5 540	8. Joint with two one-piece connectors "Confirmat"	5 620	1,01
9. Joint with two connectors with screw and cross dowel	4 420	9. Joint with two connectors with screw and cross dowel	5 870	1,33
Note: The end haunched mortise and tenon joint (№3 in Fig. 1) and the **T**-shape through mortise and tenon joint with shoulders, type B (№4 in Fig. 2) are not included in this Table because they do not have an identical counterpart to be compared with.				

The data from Table 1 and Figure 4 indicates that the T-shape corner joints of structural elements with cross section of 50 x 30 mm made of sweet chestnut solid wood have greater stiffness coefficients than the ones of the end corner joints – from 1 % to 33 %, on an average about 11,2 %.

The reason for that is the bigger distance between the faces of structural elements of the T-shape corner joints and as a result of that – the failure of the solid wood under bending load happens comparatively harder than the one of the end corner joints. The corner joints with bigger failure force have bigger stiffness coefficient.

The hierarchy of the stiffness characteristics of the different types of end and T-shape corner joints is analogous and corresponds to the conclusions of the previous publications (Kyuchukov *at al*. 2008[a], Kyuchukov *at al*. 2008[b], Kyuchukov *at al*. 2009, Kyuchukov *at al*. 2011[a], Kyuchukov *at al*. 2012[a]).

3. CONCLUSION

The comparative analysis of the results of the investigation on the influence of the type of the end and T-shape corner joints of the structural elements with cross section of 50 x 30 mm made of sweet chestnut solid wood on their stiffness characteristics under compression bending test gave reason to the following general conclusions and recommendations:

■ The type of the joints has a determining influence on their stiffness characteristics under bending load.

■ The gluing of the structural elements made of solid wood with up-to-date polyvinylacetate adhesives provides more strength of gluing under shear loading compared to the standard requirements (8 N/mm^2). This results in a higher stiffness of the corner joints under bending load. The necessary condition for that is to make the glued corner joints with a tigthness from 0 to 0,15 mm.

■ The area of contacting surfaces of the joints of the structural elements made of solid wood has a tremendous influence on their stiffness characteristics.

■ The **T**-shape corner joints have on an average about 11 % greater stiffness coefficients than the ones of the end corner joints.

■ The glued corner joints of the structural elements made of sweet chestnut solid wood have greater stiffness coefficients under bending load from 1,45 to 2,33 times than those of the dismountable ones.

■ The corner joints with dowels have on an average about 13 % lower stiffness coefficient than the ones of the mortise and tenon joints and about 76 % higher stiffness coefficient than the ones of the dismountable corner joints.

■ The type of the connecting elements has a considerable influence on the stiffness characteristic of the dismountable corner joints of the structural elements made of sweet chestnut solid wood. The difference in stiffness coefficients withing the groups of end and **T**-shape corner joints is on an average about 17 % and 11 % respectively.

■ The established values of the stiffness coefficients of the corner joints of the structural elements have to be taken into account when choosing the type of the joints in the construction of designed models of chairs made of sweet chestnut solid wood.

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TIMBER CONSTRUCTION OF SLOVENIAN CONTEMPORARY ARCHITECTURE

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ABSTRACT

Considering the growing importance of energy-efficient building methods, timber construction will play an increasingly important role in the future. Today, wooden buildings in Slovenia present an important part of all domestic buildings constructed. This study is focused on the reasons pertaining to wooden building and the possibilities of increasing the use of timber in Slovenia. Issues, like public attitude towards wooden buildings and its advantages were examined by a Slovenian public opinion survey. The positive trend towards wooden construction is dictated by international guidelines, where a wooden building is an important starting point, not only for low-energy, but also low-emission building with exceptional health and safety aspects. Renewable building materials should already be integrated into the early phases of building planning. An increasing need for renovation is going to be one of the most extensive tasks we shall face in the coming years. In order to further enhance the interest for wooden buildings a specialized portal for wood building in Slovenia has been established.

Keywords: timber construction, sustainable development, public opinion, residential building, Slovenia

1. INTRODUCTION

Wood was a fundamental material in Slovenian architecture until the 19th century. First, at least partially brick building are from the early middle ages. Because of fires, the state limited building with wood construction with regulations and rules, but real decrease started in the 20th century due to industrial production of new advanced materials. A hundred or more years old timber massive buildings suggest a highly developed culture of carpentry, building culture in the wood on the basis of experience and extensive carpentry skills. Paying attention to the traditional timber construction in the planning of the new, improved and modern is the only path towards preserving a nation's culture and the features of the Slovenian cultural landscape. Slovenian contemporary timber architecture is taking into account the standards and the values that derive from the space of the existing cultural construction.

Most traditional timber structures in Slovenia are hayracks (Figure 1). They are used during the summer months, making excellent hay from the soft meadow grasses, and in the autumn. Many were built in the 17th century from oak and beech with carefully shaped and carved beams. The hayracks in Slovene ethnic territory, developed into several forms, types and conceptual variations. Since they were built by carpenter teams, which each in their period followed a typical and distinctive concept.

The construction of buildings in Slovenia represents more than half of the construction industry, whereby three fourths of the activities are intended for the construction of new buildings and only a small share for renovation. The biggest share (47%) of existing buildings are represented by residential buildings; more than half of the residential buildings are made of brick (56%), 16% are concrete and a mixed construction and the rest of the materials including wood are represented to a smaller extent.

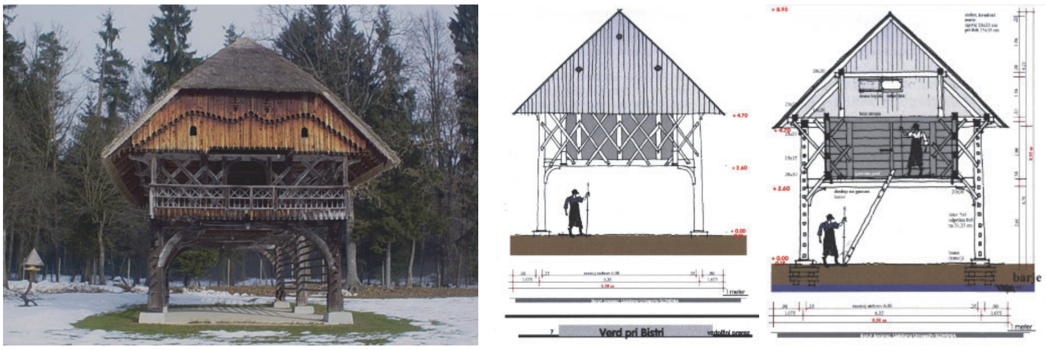

Figure 1 *Slovenian hayrack in Bohinj, the proportional analyses of hayrack structure [Juvanec (2011)]*

Wood construction in Slovenian is on rise; however. In 2011 [SORS], the percentage of pre-fabricated houses built exceeded 30% of all one and two family houses built and the percentage is expected to increase. In addition to the production of bigger companies, which are united under the section of Slovenian producers of pre-fabricated houses a non negligible amount of wooden houses have appeared lately, constructed by the undertakings themselves and through smaller tradesmen (carpentry workshops) [Kitek Kuzman (2010)]. The board of carpenters at the Chamber of Crafts has more than 500 carpenters. According to the trends in other Alpine regions, the percentage of construction through carpentry workshops will increase even more.

The dominating methods of wood construction in Slovenia include frame construction, skeletal and massive construction. Most companies on the market offer houses with wood frame construction: Jelovica hiše, Marles hiše Maribor, Rihter hiše, Kager hiša, Lumar, Riko and Rima hiše (Figure 2).

Figure 2. *Panel construction, Wood frame construction, Solid wood construction*

The components of wood-frame construction are wooden wall sections assembled from studs and crossbars of various dimensions. Various panels may be used for the exterior and interior faces (e.g., drywall panels, gypsum fiberboard, particleboard, wood-cement panels, wood fiberboard, oriented strand board, and plywood). The space between panels is filled by thermal insulation (mineral, glass or rock wool, lately also natural materials are frequently used: cellulose, wool, coconut, hemp, cotton). Ceiling structures consist of wooden ceiling beams of different cross-sections, with panel lining from both sides made and insulation of larger density (mineral wool). A ceiling structure allows the use of floating floor construction for better sound insulation (i.e., concrete screed).

Wood Products per Capita Consumption

The per-capita consumption of primary wood products is defined by production, import and export of selected primary wood products according to FAO definitions and population. The indicator covers the consumption of sawn wood and wood based panels (veneer, plywood, particle boards and fiberboards). The calculated values of wood products per capita consumption indicate the extent of wood use in construction and the extent of further processing of primary wood products into final wood products, e.g. furniture.

Europe per-capita consumption of primary wood products is lower compared to North America. Finland, Sweden and Austria have the largest extent of wood and wood based panels use in construction and in secondary processing (packaging, furniture, etc) in Europe. Slovenian wood consumption is according to official input raw data relatively low compared to available wood resources but nevertheless higher than European average. Analysis done by Slovenian Forestry Institute indicates that the real consumption may be in the range 0,60-0,70 m^3/capita (Figure 3).

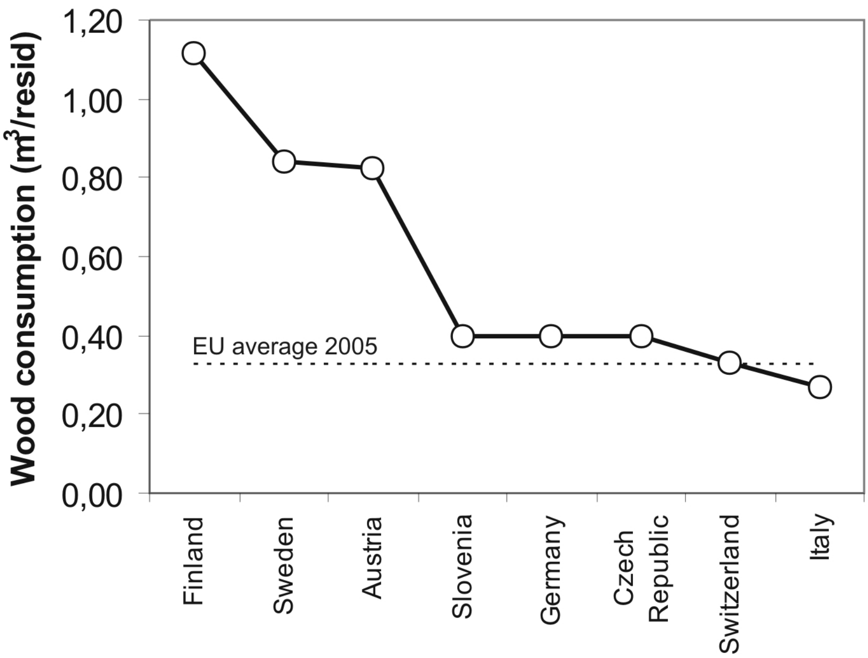

Figure 3. *Wood products per capita consumption in selected EU countries, 2005*
Source: UNECE - analyzed by M. Piškur, Slovenian Forestry Institute, 2010

2. TENDENCY TO BUILDING WITH WOOD

2.1 Multi-storey wooden buildings

Multi-storey wooden building offers great opportunities in residential and public construction. Producers and investors in Slovenia have shown a desire to build multi-storey wooden residential buildings and structures of larger dimensions. In Slovenia there is no height restriction or restriction for number of floors for the buildings with wooden structure in the terms of earthquake risk, but there is a restriction set in terms of fire safety.

Most countries in Europe and Scandinavia set this limitation on the basis of fire safety, but in the earthquake-endangered countries limitations in the number of stories are set primarily due to earthquake effect on wooden framework construction.

Some kind of start and guidelines for multi-storey construction in Slovenia represent multi-storey buildings, built in the seventies. The first multi-storey prefabricated wooden building was built in Slovenia in 1977, reflecting on for those times highly developed technology.

2.2 Public buildings

Communities today support the wood! We made a research project looked at Slovenian communities as a potential investors. Most of them agree that wood is absolutely suitable for kindergartens, schools and settlements and a little bit less for new public buildings.

The reason is that in past in Slovenia there weren't build many. Further on we were interested in investing more money for healthy environment with positive impact on people. About 79% agree, 17% disagree and about 4% are not determinate (Figure 5, 6).

Hotel Siziano, Italija
leto izvedbe 2012
izvajalec Kager hiša d.o.o.
površina 7.420 m^2
etažnost P+2 leseno

Hotelski kompleks Limone Piemonte, Italija
izvajalec Rima Hiše d.o.o.
površina 4.192 m^2
etažnost P+2+M leseno

Waldorfska šola, Ljubljana
leto izvedbe 2012
izvajalec RUBNER, ingenieurholzbau d.o.o.
površina 1.718 m^2
etažnost P+2+M leseno

Lesoteka, trgovsko poslovni objekt, Radlje ob Dravi
leto izvedbe 2012
izvajalec GLI d.o.o.
površina 442 m^2
etažnost P+1 leseno

Turistični objekt hotel Planinka, Ljubno ob Savinji
leto izvedbe 2011
izvajalec Rihter d.o.o.
površina 1.080 m^2
etažnost K klasična P+1+M leseno

Mladinski hotel Punkl, Ravne na Koroškem
leto izvedbe 2011
izvajalec Kograd IGEM d.o.o
površina 518 m^2
etažnost P+1 leseno

Stanovanjska hiša, Ljubljana
izvajalec Lumar IG d.o.o.
površina 385 m^2
etažnost P+1 leseno

Stanovanjski objekt (Lazio) (Spina), Rim, Italija
leto izvedbe: 2011
izvajalec Riko hiše d.o.o.
površina 179 m^2
etažnost P+1+M leseno

Hotel Jolly, Ponte di Legno, Italija
leto izvedbe 2011
izvajalec Riko hiše d.o.o.
površina 1.042 m^2
etažnost P+3 lesena

Poslovno skladiščni objekt, Komenda
leto izvedbe 2011 prva faza
izvajalec Ekoprodukt d.o.o.,
površina 1.156 m^2 prva faza, 2.500 m^2 druga faza

Visitor center- doživljajski park Tayto, Irska
leto izvedbe 2010
izvajalec Smreka d.o.o.
površina 905 m^2
etažnost P+1 leseno

Večstanovanjski objekt TAMPOIA, Milano, Italija
leto izvedbe 2010
izvajalec Jelovica hiše d.o.o.
površina 713 m^2
etažnost P+1+M leseno

Večstanovanjski objekt Sončna vila, Bovec
leto izvedbe 2010
izvajalec Jelovica hiše d.o.o.
površina 640 m^2
etažnost P+1 leseno

Osnovna šola Tinje, Tinje
leto izvedbe 2010
izvajalec Marles hiše Maribor d.o.o.
površina 1.872 m^2
etažnost P+3 +M leseno

Osnovna šola Polskava, Polskava
leto izvedbe 2009
izvajalec Marles hiše Maribor d.o.o.
površina 1.768 m^2
etažnost P+2 +M leseno

Hoteln Chalet 1400, Italija
leto izvedbe 2008
izvajalec Biva hiše d.o.o.
površina 950 m^2 montažnega dela / 210 m^2
etažnost 2+M leseno

Figure 4. *Multi-storey wooden buildings [Kitek Kuzman (2012)]*

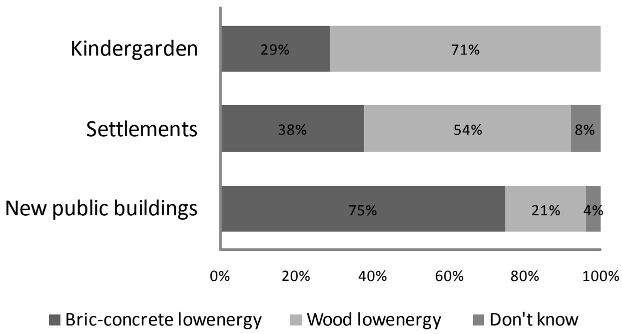

Figure 5. *For what type of buildings is timber suitable?*
Source: The Slovenian public opinion survey on wooden buildings (2)2011,
University of Ljubljana, Biotechnical faculty,
Department of wood science and Technology

Name | Youth Hostel Punkl
Year | 2012
Architecture | Maruša Zorec, Arrea d.o.o.
Structural engineer | CBD d.o.o.
Energy efficiency | low-energy, 22 kWh/(m^2a)
Surface | 518 m^2
Construction system | timber massive construction (Xlam system)
Construction time | 4 months
Investor, financed by Slovene Gradec community
http://www.punkl.si/
http://www.lesena-gradnja.si/html/pages/si-baza-podatkov-mladinski-hotel-punkl.htm

Figure 6. *An example of public timber building built from investor community: Youth hostel Punkl*

3. THE MAIN CONSTRAINTS BY BUILDING WITH WOOD regarding regulations and challenges regarding to regulations which have to be faced by the wood construction in Slovenia

The main constraint is the fire regulation. There are also some doubts about seismic safety, but last research and tests showed extremely well behavior. The outcomes from research are still not included in design standards, but in practice exists some experts on both fields which are able to design also taller timber buildings on the base of research outcomes or on the base of state of the art in the field of fire regulations and seismic safety of innovative wooden building systems.

There is lack of regulation and design methods, therefore it is to complicate to design and proof appropriateness of the building and its safety according to existing knowledge in practice. On the base of that many investors, architects and engineers avoid design in timber construction system. The regulation shell be set on European level. It is a pity that Xlam system, which was developed in Europe fifteen years ago was accepted in Canada and USA from EU five years ago and they already published standards for this product and regulate this innovative building system! With this construction system is very big development potentials especially on multi storey buildings up to 10 stories and bigger industrial and official buildings [Sutton *at al.* (2011); Hristovski *at al.* (2012)].

Decree on Green Public Procurement

Decree on Green Public Procurement (2011) entered into force in December 2011. The Decree provides minimum mandatory environmental requirements and their involvement in the public procurement processes, and it also includes recommendations for achieving higher environmental standards. The purpose of this Decree is to lower the negative impact on the environment through public procurement of environmentally less burdensome goods, services and constructions, and thus lead the private sector and consumers by example. The minimum amount of wood or wood products installed in newly constructed public buildings is 30% vol.

4. DISCUSSION

In Slovenia, it has already been proven that wood is traditional material in the national architecture but today modern times have set us new challenges. In addition, the development of science and technology has even made it possible to always use new methods for this environmentally friendly and renewable material. Due to the flooding of the market until 2025 a decrease in the construction of new apartment buildings is expected in Slovenia. Due to the need for a decrease in energy consumption in buildings, a complete renovation of buildings is planned within a framework in which a big opportunity can be presented by the wood construction renovation of existing buildings. International guidelines also dictate a positive trend in wood construction, where wood construction is in great expansion and represents an important starting-point not only for low-energy but also for low-emissions construction with exceptional views on health and security.

Focus in the region are timber public buildings, multi-storey buildings, wood extensions, designing according to carbon footprint calculations, energy-plus-house renovations because expectations of the modern society are growing increasingly higher. Apart from a high level of comfort, the focus has also shifted to easy-to use, environmentally-friendly building components that save energy and require minimum costs and thermal renovation allows for significant energy savings [Šijanec Zavrl (2008)]. Also the use of glazing surfaces in timber structures is becoming an important issue of energy-efficient construction. Our scientific work in the field of energy efficiency of buildings concentrates on researching design models of energy-efficient timber buildings, which combines the knowledge of architecture, timber construction and building physics [Žegarac Leskovar *at al.* (2012)].

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SWOT ANALYSIS OF WOOD INDUSTRY IN THE REPUBLIC OF MACEDONIA

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ABSTRACT

This paper analyses the situation with wood industry in the R. of Macedonia, as well as the inside and outside factors which affect this situation and performance of the wood industry. Therefore, by application of SWOT analysis, we have identified the inside strengths and weaknesses and the outside opportunities and threats in the woodproduction plants. It is one of the tools used to determine the direction of development of the wood industry.

Key words: wood industry, situation, SWOT analysis

1. INTRODUCTION

A prerequisite for making grounded development assumptions and forectasts is recognition of the strengths and weaknesses, on the one hand, and opportunities and threats, on the other hand. The hectic pace of life and the severe competition in the business market forces the companies to have to opt for a way to deal with that competition. SWOT analysis is a quality analytic method by which, assessing four factors, certain phenomena are identified and the future is forecast and planned. This analysis is a real asset when creating and planning development strategies for a company or a sector.

Each company within a sector must take into account the inside organization and the outside environment. In that respect, this analysis could be described as a survey of the inside strengths and weaknesses and outside opportunities and threats which the company, i.e. the sector, faces.

2. SUBJECT AND GOALS OF THE STUDY

The subject of studying in this paper is analysis of the conditions in wood industry in the R. of Macedonia and the SWOT analysis. The SWOT analysis identifies the strenghts and weaknesses as inside factors, and the opportunities and threats as an outside factor in the environment of this industry.

The goal of this study is by minimization of the weaknesses and threats and maximization of the strengths and opportunities, to determine guidelines for development planning and decision making in this industry. Deduction and induction methods were applied in the study, i.e. the method for analysis and synthesis of the data. The data used was quantitative and qualitative.

3. GENERAL INFORMATION ON SWOT ANALYSIS

SWOT analysis was first applied in the 1960s by the research team Albert Humphrey, Marion Dosher, Otis Benepe and Birger Lie, in the University in Stanford. Their goal was, while working on the project, to find out why corporate planning had taken a wrong direction. They wondered which were the pluses and minuses of the current performance and the pluses and minuses the future brings. The present and future plusses were called Satisfactory and Opportunity respectively, and the present and future minuses were called Fault and Threat respectively, getting the acronym SOFT. Later it was changed into SWOT. This SWOT analysis became particularly popular in the 1970s.

SWOT analysis is in fact a rather flexible method that connects the analysis results of studying the inside and ouside factors in the environment which affect the development of a company or a sector. It is in fact an instrument of the managerial team which creates the business strategy of the respective company or sector. (Table 1).

Table 1. *Scheme of SWOT analysis*

environment	positive	negative
inside	strengths S	weaknesses W
outside	opportunitieses O	threats T

When making the analysis, the questions asked are always which are the inside strengths and weaknesses and outside opportunities and threats the company or the sector faces. The strengths must be used the best possible and the weaknesses must be minimized, i.e. to take advantage of the opportunities and to minimize the threats in the relevant company or sector. SWOT analysis is a perfect tool for planning development strategy for the company or the sector.

When planning the development strategy, all the four aspects of the SWOT matrix must be taken into consideration.

Table 2. *SWOT matrix*

Environment factors	opportunities O	threats T
Company factors		
strengths S	SO combination	ST combination
weaknesses W	WO combination	WT combination

The strengths and weaknesses of the companies in the matrix stand opposite to the opportunities and threats. Afterwards the matrix is systematically studied, following the combination of the environment factors and the company factors.

The elements of SWOT analysis, when talking about the strengths (S) and weaknesses (W) are as follows: (S): geographical location, size of the company, infrastructure, choice of products, industrial tradition, production capacity, product quality, reliability of deliveries, flexibility of the production programme; (W): high production costs, problems regarding sales, outdated technology, how fast decisions are made, lack of marketing data, difficulties in conquering new markets.

When talking about opportunities (O) in SWOT analysis, they are the following ones: proper usage of the capacities, organization of the company, segmentation of the market, quality of the competitors' products, supply of raw materials and basic materials, labour market, expansion of the market. As to the threats (T) in SWOT analysis, they are as follows: requirements related to environment protection, the Government economic policy, high inflation, demographic development, purchase capacity of the customers, competition coming from foreign markets, expensive loans, structure of the customers, chances for substitution of the products etc.

This paper offers an analysis of the present situation in the wood industry in the R. Macedonia, followed by SWOT analysis.

4. CURRENT SITUATION WITH THE WOOD INDUSTRY

The present sistuation with the wood industry will be presented by the available statistical data, using the following parameters: index of industrial production, number of employees, the ratio export import, average net pay for the period 2006-2011 in the field of wood treatment and wood products (excluding furniture) and furniture manufacture. Industrial production is given by chain indexes (Table 3).

Table 3. *Chain index of wood production*

	2007/2006	2008/2007	2009/2008	2010/2009	2011/2010
wood and wood products treatment, excluding furniture	100,1	76,5	58,5	147,8	78,5
furniture manufacture	109,3	266,5	71,6	80,5	124,1

The data from the table above show that there is no regularity in the development of industrial production. It had gone up and down throughout the years analysed, depending on the demand. The number of employees in the period analysed, expresed in indicators, is shown in the table below (Table 4).

Table 4. *Number of employees*

	2007	2008	2009	2010	2011	PGS
wood and wood products treatment, excluding furniture	3264	2913	2867	2246	2349	-8,57
manufacture of furniture	3818	4158	4060	3092	3413	-2,83
Total	7082	7071	6927	5338	5762	-5,29

The data indicate that the number of employees in the wood industry for the period 2007-2011 has been dropping by -5,29% per annum. In the area of wood and wood products treatment, the number of employes decreases by PGS of -8,57%, whereas in the furniture manufacture it drops by PGS of -2,8%. The avarage net pay paid to the employees in wood and wood products treatment industry and in furniture manufacture industry is shown in table 5

Table 5. *Average paid net pay*

	2007	2008	2009	2010	2011	PGS
wood and wood products treatment, excluding furniture	8667	8310	9105	10260	11540	12,46
manufacture of furniture	6919	8159	10223	11301	11781	6,91
Total in all sectors and departments	14548	16096	19957	20553	20847	8,60

The data from the table above indicate that the net pay paid to the employees working in wood and wood products treatment industry is drastically lower (by about 50% throughout the period analysed), compared to the pay of the employees from ohter secotors and departments.

If looking separately at the sectors, we will see that the average net pay paid to the employees working in wood and wood products treatment industry grows faster, with PGS of 12,46%, unlike the furniture manufacture industry, where the PGS amounts 6,9%. The average total net salary for all sectors grows with PGS of 8,60%.

The situation with export and import of wood products is presented by the export import ratio (Table 6).

Table 6. *Export import ratio*

	2007	2008	2009	2010	2011	PGS
wood and wood products treatment, excluding furniture	19,27	14,12	12,41	12,69	10,22	-17,18
manufacture of furniture	28,66	30,08	29,53	71,31	82,08	23,13

The figures from the above table indicate that the export import ratio in the field of wood and wood products treatment was 19,27% in 2007, but fell to 10,22% in 211, which indicates a dropping tendency, with PGS of -17,18%. Regarding manufacture of furniture, the export-import ratio is higher and ranges between 28,66% in 2007 and 82,08% in 2011, showing thus a growing tendency, with PGS of 23,13%.

5. SWOT ANALYSIS

SWOT analysis for wood industry in the Republic of Macedonia was made based on the available data for that area and consultations made with a few experts in this area. The analysis is given in Table 7.

Table 7. *SWOT analysis of wood industry*

Pozitive factors	
STRENGHTS	**OPPORTUNITIES**
- working tradition - improved quality of performance - production capacities - infrastructure - export oriented - available labour - existing cluster for wood industry - flexibility of the producers - high quality products	- your own retailing network - policy of public procurements - labour market - expansion of the markets - furniture designing, assembly and repair services - attractive young staff - computerization and automotization of production - application of information technology and electronic networks - using laboratory for furniture testing - better conditions for taking loans - legislation for import of furniture from non-EU countries - establishment of furniture sales centres
Negative factors	
WEAKNESSES	**THREATS**
-promotion of products - speed of making descisions - lack of information about the market - slow conquering new markets - non-holding ISO standards by majority of producers - import of basic materials - import of raw materials - import of basic raw materials - lack of distribution centre for furniture - high interest on loans - lack or unique design – copying - lack of well skilled and qualified expert staff - high costs for raw materials - lack of certification of Macedonian wood	- high costs for attendance of fairs - environment-related requirements - purchasing capacity of the customers - structure of the customers - strong competition at foreign markets - protection of the EU countries at the furniture market - speedy development of new technologies - fast development of new materials - illegal operation – grey economy - competition with prices - competition from imported products

6. CONCLUSIONS

Analysis of the situation with wood industry in the Republic of Macedonia gives the foolowing conclusions:

Wood industry in the Republic of Macedonia is an important area in the total industrial production and has a long-lasting tradition.

For the period analysed – 2007/2011 – industrial production regarding wood processing and furniture manufacture does not feature some typical development dynamics, i.e. it had gone up and down depending on the demand. The number of employees in wood industry has been decreasing, with average annual rate of -5,29%. In the field of wood and wood products processing, the number of employees has been dropping with PGS of -8,57%, whereas in the field of furniture manufacture it falls with PGS of -2,83%. Average paid net pay in the field of wood and wood products processing in the period analysed grows with PGS of 12,46%, and in the furniture manufacture field it grows with PGS of 6,91%. In total for all sectors, the average net pay rises with PGS of 8,60%. The import export ratio in wood production varies between 19,27% in 2007 and 10,22% in 2011, and tends to continue decreasing. The import export ratio in furniture manufacture tends to increase, ranging between 28,66% in 2007 and 82,08% in 2011.

SWOT analysis proved that in the Republic of Macedonia there is a great number of export oriented companies. Some of the weaknesses are that many of these companies have not yet implemented the ISO standards, which definitely is a drawback if you are export oriented. In addition, the furniture manufacturers are dependent on imported raw materials (plywood, mediapan panels) and basic materials. Interests rates of loans are high, which makes production and manufacture dearer.

The opportunities for development of this industry are in expansion of the markets, usage of favourable loans, quality control of the imported furniture and basic materials, monitoring the markets' requirements by market research etc.

In order to define the development strategy of wood industry, more comprehensive and more in-depth study is needed, for which funds is necessary. Thanks to them we could determine the development directions and trends in wood industry in the Republic of Macedonia and would be able to establish development strategies.

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THERMAL CHARACTERISTICS OF SOME WOOD – BASED PANELS USED IN CONSTRUCTION

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ABSTRACT

Wood–based panels are widely used not only for furniture but also for construction purposes, especially for prefabricated houses. They can be used for flooring, roofing, walls and as insulation. Although wood–based panels used as load bearing construction materials have to have good mechanical properties it can be determined that they even have relatively good thermal characteristics (low thermal conductivity). Despite the fact that thermal characteristics of panels are related to the density of panel it is also evident that there is a difference among different panels related to size and type of constituent. The aim of paper is to present thermal characteristics of some wood–based panels used in construction. It was determined that thermal characteristics (thermal diffusivity) depend on the type of constituent, type of panel and its density.

Key words: wood–based panels, thermal conductivity, thermal diffusivity, density

1. INTRODUCTION

The care for environment, lowering the greenhouse gas emission hence construction of energy efficient building forced human into using materials that have high strength and good thermal characteristics. When looking for such material wood and wood-based composites are always accounted as such construction material. Increased us of wood and wood-based composites hence emphasized not only their good mechanical properties (related to their density), sorption properties but also their low thermal conductivity.

Several authors like Kollmann et al. (1975), Suzuki and Saito (1994), Albrect (1997) and Reyer et al. (2002) reported relatively low thermal conductivity of wood-based panels. Thermal conductivity reported was from 0,04 to 0,14 $W \cdot m^{-1} \cdot K^{-1}$ and in some cases up to 0,22 $W \cdot m^{-1} \cdot K^{-1}$. Kawasaki and Kawai (2006) investigated the thermal insulation properties of wood-based sandwich panel where they used plywood for surface layer and low density fibreboard as core layer. They have determined thermal conductivity values between 0,07 and 0,077 $W \cdot m^{-1} \cdot K^{-1}$ for densities between 0,34 and 0,41 g/cm^3. Good thermal insulation properties of different wood-based panels were also reported by Sonderegger and Niemz (2009), what is shown in table 1.

Sonderegger and Niemz (2012) investigated thermal conductivity of soft fibreboards. They have determined that thermal conductivity increases with increasing density.

TenWolde et al. (1988) listed some thermal diffusivity values for wood and wood–based panels. Average value for wood was $0{,}15 \times 10^{-6}$ $mm^2 \cdot s^{-1}$ (at 24°C and MC=12%). They also reported that thermal diffusivity decreases with increasing density (density between 0,31 and 0,72 g/cm^3). Some values about thermal properties were also given by Adl–Zarabi and Boström (2004). They determined that thermal diffusivity depends on the temperature to which material was exposed and its moisture content. The conductivity of particleboard was between 0,164 $W \cdot m^{-1} \cdot K^{-1}$ (at 20°C) and 0,191 $W \cdot m^{-1} \cdot K^{-1}$ (at 105°C), while diffusivity was between 0,122 $mm^2 \cdot s^{-1}$ and 0,179 $mm^2 \cdot s^{-1}$ and was decreasing with increasing density. Higher thermal diffusivity (between 0,22 and 0,32 $mm^2 \cdot s^{-1}$) and lower conductivity (0,088 and 0,105 $W \cdot m^{-1} \cdot K^{-1}$) was determined at low density fiberboard impact of particleboard structure (share of core layer) and thermal diffusivity was investigated by Jan (2011).

The aim of paper is to present thermal characteristics of some wood–based panels like insulation fibreboard, façade fibreboard, OSB, particleboard, MDF and plywood, used in construction.

Table 1. *Data of thermal conductivity of some wood-based panels (Sonderegger in Niemz, 2009)*

	Thickness in mm	**Density in g/cm^3**	**Thermal conductivity in $W \cdot m^{-1} \cdot K^{-1}$**
Beech plywood	25	0,680	0,1304
Particleboard	16	0,600	0,0965
OSB	18	0,560	0,0959
MDF	16	0,700	0,0974
MDF wall panel	15	0,530	0,0761
HDF	7	0,780	0,1138

2. MATERIALS AND METHODS

For the determination of thermal characteristics of wood-based composites we used composites that can be found also in the construction of prefabricated houses:

- plywood (PW): thickness 20 mm, density 0,78 g/cm^3, beech veneer, 11 layers;
- OSB (OSB): thickness 18 mm, density, density 0,65 g/cm^3;
- structural board (SB): thickness 22 mm, density 0,71 g/cm^3; SB is similar to particleboard except in case of SB coarser particles are used for surface layer;
- particleboard P5 (PB P5): thickness 19 mm, density 0,68 g/cm^3;
- medium density fibreboard (MDF): thickness 18 mm, density 0,82 g/cm^3;
- wood fibre insulating board for exterior wall panelling (fac. FB): thickness 60 mm, density 0,20 g/cm^3;
- insulation fibreboard (insul. FB): thickness 170 mm, density 0,06 g/cm^3;
- extruded polystyrene (XPS): thickness 40 mm, density 0,03 g/cm^3.

Prior to exposure all boards were placed into climate chamber for 14 days. Temperature in climate chamber was set to 20°C, while the relative air humidity was set to 65%.

Samples 100×100 mm were afterwards on one side exposed to temperature that was corresponded to the temperature difference of 40°C. Setup of experiment is shown on Figure 1.

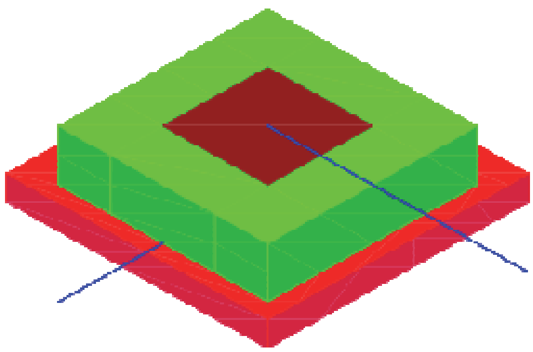

Figure 1. *Schematic layout of experiment – measuring of temperature*

As show on Figure 1 samples were exposed to heat only on one side while other were protected with extruded polystyrene (XPS) boards (also upper side). The reason behind such protection was to prevent heating through edges and cooling of opposite surface. Temperature measuring cells were placed between the heating plate and opposite surface. Measurements were collected by the equipment every second until there was no evident increase in temperature for at least 30 minutes.

From results θ (equation 1) and thermal diffusivity D (equation 2) were calculated (Koloini, 1985).

$$\Theta = \frac{T_t - T_{Min}}{T_{Max} - T_{Min}} \qquad (1)$$

where:

θ............change in temperature;
T_{Max}........maximal temperature in °C;
T_{Init}.........initial temperature in °C;
T_t...........temperature in time t in °C.

$$D = \frac{\pi \cdot \left(\frac{d}{2}\right)^2}{4} \cdot \left(\frac{d\Theta}{d\sqrt{t}}\right)^2 \qquad (2)$$

where:

D...........thermal diffusivity in $mm^2 \cdot s^{-1}$;
t.............time in sec;
d............thickness in mm.

Thermal diffusivity (D) is a value that gives us information how quickly or slowly material can change its temperature when exposed. Materials with higher thermal diffusivity will quicker reach new equilibrium condition, while materials with low thermal diffusivity will need more time to reach new equilibrium condition. According to Incropera et al. (2006) with thermal diffusivity we get information about the ability of material to conduct thermal energy in relation to its ability to store thermal energy.

The time ($t_{\theta=0,5}$) and temperature ($T_{\theta=0,5}$) to θ=0,5 was also recorded with regard to the type of material.

3. RESULTS AND DISCUSSION

As it can be seen in Figure 2 type of panel plays important role when thermal characteristics are in question.

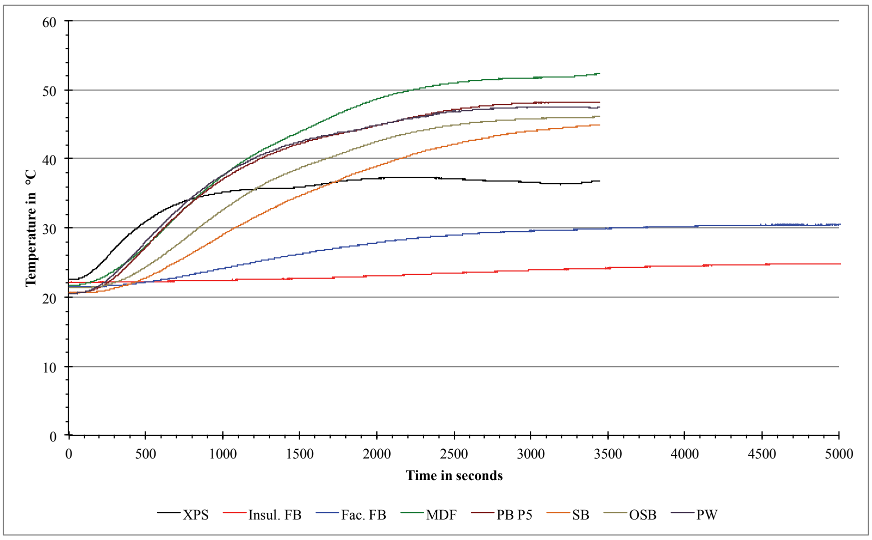

Figure 2. *Temperature increase with regard to the exposure time and type of panel at ΔT=40°C*

As we can see there is a difference in the slope of curve, maximum temperature and also in time and temperature to θ=0,5. This data are more clearly shown in Table 2.

Table 2. *Maximum temperature (T_{Max}), time ($t_{è=0,5}$) and temperature ($T_{è=0,5}$) to è=0,5 with regard to type of panel*

Material	T_{Max} in °C	$T_{è=0,5}$ in °C	$t_{è=0,5}$ in minutes
XPS	37,28	29,90	7,30
Insul. FB	24,96	23,55	42,81
Fac. FB	30,52	25,99	23,79
MDF	52,48	37,10	16,20
PB P5	48,25	34,45	13,98
SB	44,99	32,78	21,98
OSB	46,38	33,86	18,04
PW	47,56	34,02	12,94

Highest and the lowest maximum was determined at boards from fibres (insul. FB the lowest and MDF the highest), while the difference between boards from veneer, strands and particles was less than 4°C. The difference among boards corresponds to the density of board (Figure 3).

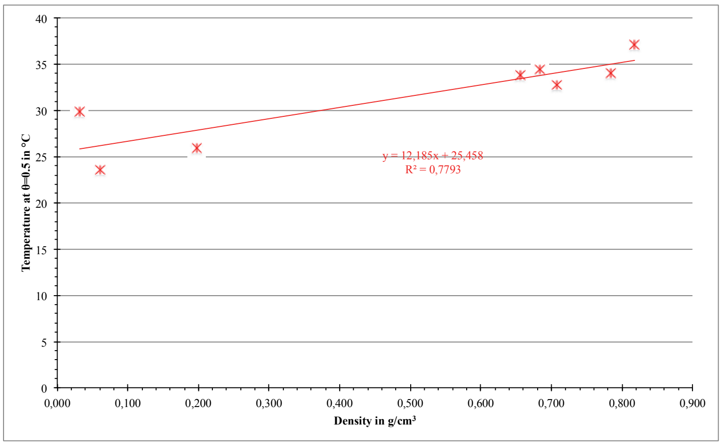

Figure 3. *Temperature at è=0,5 with regard to board density*

As it can be seen from Figure 3 the lower the density of board the lower is temperature. Comparison of insulation effect (temperature decrease) is shown on Figure 4.

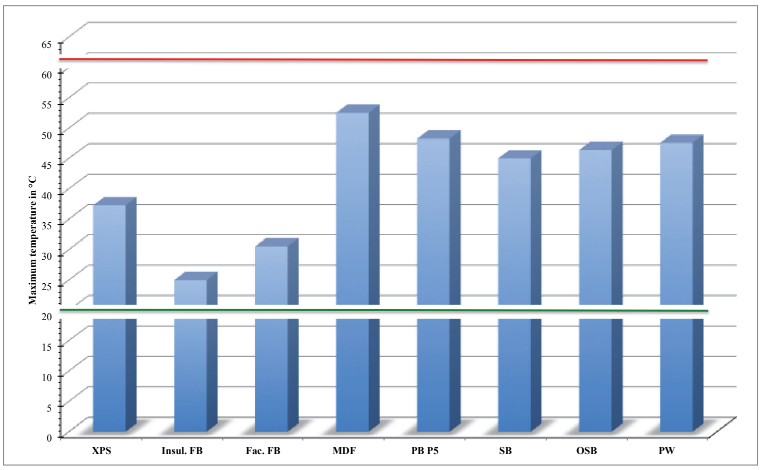

Figure 4. *Maximum temperature with regard type of board*

(– temperature of heat plate; – temperature of surrounding)

As we can see the highest decrease in temperature can be observed at fibreboard used for insulation (insul. FB), while the lowest at MDF. The highest insulation potential can be observed at insulation and façade fibreboard where temperature difference was the highest (37°C respectively 32°C). At insulation and façade fibreboard the time needed to reach θ=0,5 was also the longest (table 2).

Comparing the results of thermal diffusivity (D), we can see that it is influenced by board type, its density and thickness (Table 3 and Figure 5).

Table 3. *Thermal diffusion coefficient (D), density and thickness with regard to panel type*

Material	t in mm	ρ in g/cm^3	D in mm^2/s
Styrodur	40	0,032	0,811
Insul. FB	170	0,060	3,807
Fac. FB	60	0,198	0,636
MDF	18	0,818	0,068
PB P5	19	0,683	0,100
SB	22	0,707	0,084
OSB	18	0,656	0,083
PW	20	0,784	0,106

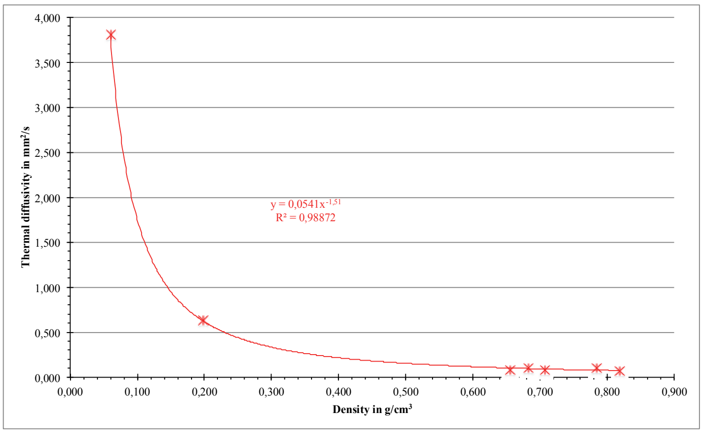

Figure 5. *Thermal diffusivity (D) with regard to the panel density*

As we can see thermal diffusivity of the wood–based materials is decreasing with increasing density. Similar was determined by Adl–Zarabi and Boström (2004). Despite the fact that thermal diffusivity (D) and thermal conductivity (λ) are related through equation 3:

$$D = \frac{\lambda}{\rho \cdot c} \tag{3}$$

where:

λ - thermal conductivity in W·m^{-1}·K^{-1}

ρ - density in kg/m^3 and

c - specific heat in J·kg^{-1}·K^{-1}

and correlating the values of thermal diffusivity (D) with the T_{Max} and $T_{\theta=0,5}$ we can see that relation between thermal diffusivity (D) and thermal conductivity (λ) is not a simple relation, especially when heterogeneous materials are in question (Salazar, 2003).

We can conclude that insulation and façade FB are good thermal diffusers compared to the other boards having higher density and lower thickness but lower thermal diffusivity.

4. CONCLUSIONS

According to the results obtained during experiment we can conclude following:
- thermal diffusivity (D), maximum temperature and time are dependent on the panel type, structure, density and thickness;
- the lowest temperature on opposite surface was determined at insulation FB, while the highest at MDF;
- difference in maximum temperature (on opposite side) between PB, SB, OSB and PW was less than 4°C.

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APPLICATION OF NEW PANEL MATERIALS IN PREFABRICATED HOUSES

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ABSTRACT

A significant number of buildings for residential and relaxation people are built as prefabricated house due to significantly lower the cost and speed of build.

The paper presents the new wood-based materials that are suitable for use in wooden prefabricated houses. Will also be described elements of prefabricated houses for which it is possible to apply some of the types of materials the wooden plate for rapid building of these houses.

Keywords: prefabricated house, wooden panel materials, application

1. INTRODUCTION

Application of prefabricated wooden buildings dating from the 1624^{th} when the English in Cape Ann, Massachusetts, built the first wooden panel buildings. From that time until today, the development and use of this type of object is experiencing major or minor ups and downs. The twentieth century was characterized by a significant development of science, the development of techniques of building facilities and production technology in general. There has been significant development of manufacturing equipment for the production of traditional building materials, but also the development of new types of building materials. Also changed significantly and the philosophy of life of people and the market in general. The globalization of markets and market changes have affected the construction techniques.

People to live and vacation are increasingly using prefabricated wooden buildings because the cost of construction of these facilities is significantly lower than conventional solid objects, during construction of these buildings is significantly shorter, and constructed buildings can meet all or most of the people's needs in terms of design, comfortableness and quality human residence.

According to data from McGraw-Hill Construction, 2011, in the USA to the total number of facilities built prefabricated buildings account for a share following sectors: healthcare facilities 49% , college buildings and dormitories 42%, manufacturing buildings 42%, buildings for public sectors 40%, commercial warehouses 37%, retail buildings 24%, hotels and motels 29%, banks 18%, garage 14%.

2. TYPES OF PREFABRICATED WOODEN HOUSES AND CONSTRUCTION TECHNIQUES

There are three types of prefabricated systems of housing used in residential construction:

- Volumetric Systems, which is characterized by a complete three-dimensional assembly of manufactured modular units produced in factory and installed in on site
- Partial Modularization Systems, which is characterized by production of standardized units or components in a factory and installed on site
- Prefabrication of Elelments, various individual systems, including frames and structural insulating panels.

The first type of construction has proven to be financially cost effective in the construction of the so-called. typical houses, where they made a number of one type of object (military dormitories, holiday resorts and the like). All components of the building, the walls, floors and ceilings are made in the factory and they are completely finished, with fitted windows and insulation, and installation systems and represent a prefabricated module on the location of construction site.

Figure 1. *Prefabricated module*

The second and third type of construction is more suitable for making so-called home. invidualnog style. These facilities differ in style and they consist of a series of standardized units, which have already been install or are subsequently installed windows or doors left open on the panel, if necessary, and a number of individual components of the houses. This type of construction of prefabricated buildings to better meet the requirements of each individual user facilities in terms of quality and comfort of your stay.

Figure 2. *Example of construction of the facility with the use of wooden frames (column-beam system) and standardized prefabricated modules or components framework*

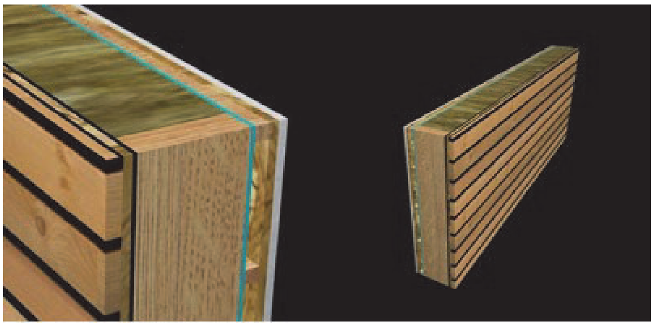
For these objects is typical application framework of solid or laminated wood as structural elements of the structure within which it is embedded isolation needed, and the application of structural insulating panels. There are several common techniques for the construction of buildings with the use of wood frame. The first technique was characterized by the use of wood as a structural element for the creation of the boards for the frame. Foundation future building is made mostly of concrete. This simple construction techniques often used in the construction of single-family houses, but also in building multi-storey.

The second technique was characterized by the use of wood for supporting the frame. Cross-laminated timber panels are used for the construction of walls and beams facility. Walls can have a high level of energy efficiency. The technique is well suited for the construction of multi-storey. The third technique is a system of columns and beams. In this case, laminated elements are used for load-bearing structural elements and may have a different cross-section. All systems framework should meet contemporary criteria for fire safety, noise and energy efficiency.

Depending on the construction standards of each country in terms of energy efficiency used different decision making panels for wall, floor and roof construction elements. Typically, external walls use panels with insulation thickness of 100-300 mm, for floor panels insulating layer has a thickness of 200-300 mm and roof panels insulating layer thickness 200-400 mm.

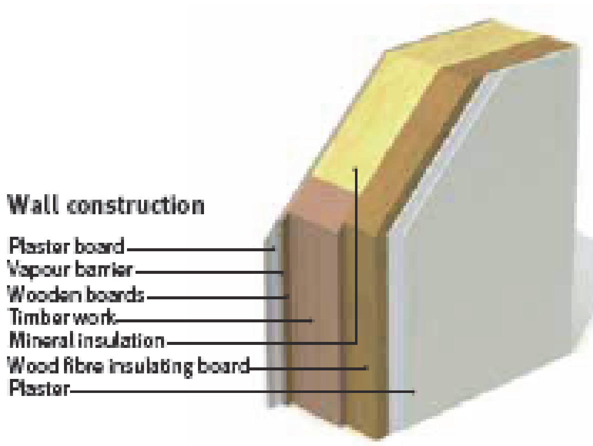
The following figure shows the typical examples of applied panels to create the exterior walls of prefabricated buildings in the USA and Turkey.

Outside walls - USA:



Machboard 21x145mm, Spruce, painted 2 times
Vertical laths 45×45 mm c/c 600 mm
Wind barrier Tyvek
Norgips GU 9mm plasterboard
Wood stud 145x45mm or 195x45mm c/c 600 C24
Insulation KL-37, 150mm or 200mm
Osb-3 15mm, (Chipboard)
Vapor barrier Pe-foil 200 mk
Wood Laths 45x45mm
Insulation KL-37, 50mm
Plasterboard GKB 12.5mm

Outside walls (Turkey):
Outer wall Thickness: 100 mm



Heat and Noise Insulation Material: 84 mm thick Polystyrene Foam (EPS) (12kg/m³) (Fire Strength: "B1" class "flame resistant" material in accordance with DIN 4102).
Carrier Panel Construction: Specially shaped Galvanized H Profile. Thickness is 1.2 mm.
Outer Wall Inner Coating : 8 mm thick cemented board
Outer Wall Inner Coating Paint : Plastic Paint (Double Coating)
Outer Wall Outer Coating Paint : Acrylic Paint (Double Coating)

Figure 3. *Examples of structural panel outside (exterior) wall*

3. MATERIALS AND PROPERTY OF MATERIAL FOR PREFABRICATED HOUSES

In the construction of the said panels are used solid wood and panel materials based on wood and non–wood plate materials. Some typical wooden materials are: chipboard, OSB, gypsum fiber boards, plywood, laminated boards, cross-laminated panel or lightweight multi-layer timber panels.

Depending on the techniques of construction, climatic and other conditions specific to each country, building standards of each country or region prescribe or recommend: minimum cross timbers, strength class structure, ie, the minimum value of certain mechanical properties, moisture content, the minimum thickness of the insulating layer and the like. For example, if the products are prefabricated building for Malaysian market humidity used plate elements should be less than 18% moisture wood is less than 22%, all the used timber should impregnate with pressure impregnated with CCA to a dry salt retention of 5.6 [kg/m^3] and the depth of penetration of CCA shall be at least 12 mm, used plywood should be waterproof, etc, that all materials have to meet the conditions of use for this climate area and the expected load.

If the production of prefabricated houses using chipboard they should have the following characteristics: modulus of rupture of a minimum of 11 N/mm2 when used for underlayment to 19.5 [N/mm^2] if you are used to build load-bearing panel building, module elasticity 1 725-3 100 [N/mm^2], hardness 2 225 [N], thermal conductivity of 0.1 - 0.14 [W/mK], and chipboard thickness greater than 16 mm should isolate the sound of 25 [dB].

Figure 4. *Example of using plywood and OSB*

OSB boards are used for the construction of wooden houses in the USA, Canada, but increasingly used in our country. In doing so, apply three types of OSB: for use in dry conditions - OSB/2, for use in humid conditions - OSB/3 and OSB/4. Bending strength OSB/2 and OSB/3 panel should be at 9-18 [N/mm^2] for boards thickness of 18-25 mm and 11-22 [N/mm^2] for plate thickness of 6-10 mm and modulus of elasticity in bending for plates of thickness should not exceed 1 400-3 500 [N/mm^2]. OSB/4 boards should have a bending strength 14-26 [N/mm^2] for board thickness of 18-25 mm and 16-30 [N/mm^2] for boards thickness of 6-10 mm and modulus of elasticity in bending for all thickness should be at
1 900-4 800 [N/mm^2]. The thermal conductivity of OSB is 0.13 [W/mK] for a mean density of 650 [kg/m^3].

Plywood is used in walls, floor and roof panels. Bending strength of plywood depends on the type and set of plywood and ranges from 19.5 - 45 [N/mm^2] and modulus 5 000-10 000 [N/mm^2].
For the construction of prefabricated houses are used and solid wood panels (cross-laminated timber panels).

These panels are made of three glued together layer thickness of 19-42 mm. Used panels thickness 60-400 mm and a length of 4.8 to 20 m. Each element prefabricated houses produced with exactly the required length and width, in which left an opening for windows and doors. The surfaces of walls, floors and roofs are sanded and panels are easy install on site with the use of a small crane.

Figure 5. *Solid wood panels*

Due to the relatively high cost and weight of solid wood panels, and to improve the mechanical and technical property of panels in prefabricated houses in the last decade to apply solid wood lightweight panels. They are suitable for application based on individual needs of prefabricated houses.

Figure 6. *Lightweight solid wood panel*

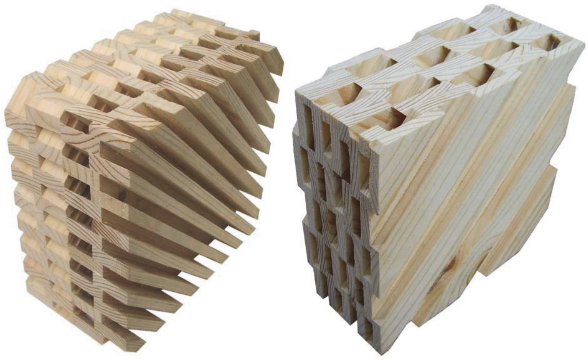


Figure 7. *Orientation of layers in the structure of the new unit*

Their density is 300-400 kg/m3 (which amounts to 60-70% of the density of using wood). Their mechanical, thermal-insulating, sound-insulating properties are of the same or better than the characteristics of wood from which they are produced.

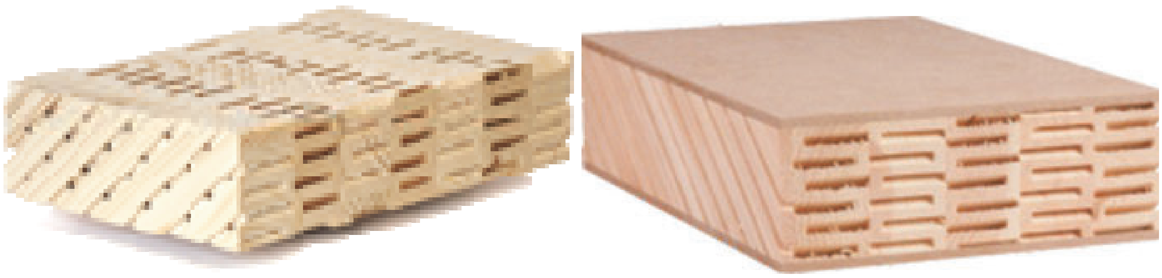


Figure 8. *Dendro-Light board*

An example of such boards are Dendro-Light boards. Thickness of board is 24 - 240 mm, width up to 2 075 mm and length up to 6 000 mm. These panels can be successfully applied for the construction of exterior walls. If the user of buildings to wants, wall built from these light panels can sheathe with plywood, OSB or other non-wood panels.

4. CONCLUSION

Prefabricated buildings can apply the last three hundred years with to a greater or lesser extent applications. They were typical for the USA, Canada and some English colonial areas. In Europe, their use as residential buildings were quite small.

Thanks to the development of construction techniques and producing technology of wooden building materials, growing market needs, the relatively low cost of building and construction of a short time, in recent decades a growing need for the construction of prefabricated buildings in our country, not only as an ancillary commercial facilities (dormitories, warehouses, retail outlets and garage), yet and as residential buildings that meet high standards in terms of energy efficiency and comfort of living in them.

The prefabricated building is used by many types of wood materials. In addition to the use of the classic board materials used and solid wood panels and solid wood lightweight panels.

Depending on the purpose, climatic conditions, terms of use prefabricated building, construction techniques, energy efficiency that the facility should meet, building standards of each country or region lay down minimum requirements for the value of certain properties of the materials used.

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UNIVERSAL KITCHEN INTERIOR DESIGN

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ABSTRACT

Interiors define arranged spaces equipped with furniture used by people, general with access and usage issues. All types of interior designs concern the interaction between people and their environment, which is a two- way process. If is taken one area such as a home kitchen, can be seen how social attitudes, developing technology and many other factors are reflected in the design of its interior.

Universal design refers not just to a final product but also to a process of designing, which includes the functional needs of people with and without physical disabilities.

This research article shows a concept of universal kitchen design, a product with both aesthetic and functional usage for everyone. The design process is based on the barrier- free designing with usage of innovation technology, in order to give access to inaccessible kitchen elements.

Kitchen counters with several height positions, cabinets with roll- out shelves and ergonomic designed kitchen parts, offer disabled people in wheelchairs or ageing population and their families accommodation of usage and free access to tools in the kitchen.

Key words: Universal kitchen design, physically disabled people, wheelchair, accessibility, functionality, aesthetics, ergonomics, anthropometric analysis.

1. INTRODUCTION

1.1 Introduction to Universal Design ("Barrier- Free Design")

Space design that gets the needs of all users during their entire life is a major goal of "Universal design" or "Design without limits". The ability to plan and design products and environments which can be used by multiple categories of users, including people with mobility limitations, people in elderly years, short people, children, people of all ages and physical abilities and disabilities are universal design features.

For specificity and different ergonomic conditions of persons with physical disabilities, standard home spaces are more than "unavailable". Therefore, when universal design reflects on housing design, we get home environments that have features that are relatively easier to use in comparison to the traditional home designs. "Universal house design" enhances the comfort, safety and convenience of the home, regardless of user's age, height or mobility.

1.2 Goal and Structure of the Research Article

This analytical research study has been carried out to present a kitchen model for wheelchair users and people with mobility impairments that reflects universal design concepts.

The main purposes of this article are:

1. To develop a model based on the concept of kitchen design, formulated as a combination of earlier studies and the criteria of universal design.

2. To present designing guidance needed to design kitchens for wheelchair users and people without physical disabilities, which can also be used as a preliminary educational tool for modifying exciting kitchens.

The further of this document is divided in two parts:

- **Approach and state of research**.
  The reader gets informed about the applied working methods used as approach to the research and basic information about "The principles of universal design", which are of interest for understanding the theme to the people who are not familiar with the "barrier-free projecting" in every segment of interior architecture and furniture design.
- **Interior equipment of presented universal kitchen model.**
  Through the projected kitchen model for disabled people who use wheelchairs or medical devices for movement and their families, is presented design approach applying the universal design principles, as well as recent innovative technologies and tools in accordance with modern trends and requirements of end users.

2. APPROACH AND STATE OF RESEARCH

2.1 Applied Working Methods

To carry out this study and design a model concept, professional literature and findings of former research on kitchens for wheelchair users were analyzed. The findings lead to thinking of trying to define a particular methodology of designing a universal kitchen space no different from the general purpose kitchen, updating the standards for the design, as well as, designing and adjusting kitchen elements for needs of persons with disabilities.

Resources such as books and references conclude this manual and give the reader an opportunity to find additional assistance in planning a home with universal design. Primary materials include plans, drawings, models, sketches, photographs and statements by designers and contemporary design critics, theorists and users of universal designs. Also published journals and internet materials are being used as source of information.

The main reasons reported as imperative to determine the theme of this work are:

- Define clearly expressed pathways that ensure consistency in design (furniture design).

- Improvement of industrial production synchronizes between housing and industrial furniture production.

- Increasing the impact of professional designers to plan relationship between quality designed kitchens and production quantity of the same.

- Improving the application of science to the furniture production, especially in the part where is specifically marked sensibility to potential users or buyers, promoting the connection between academic institutions dealing with designers and with the economy.

Design is a general methodology that links all stages of a design system, from idea to its final realization. For these reasons methodology does not provide any solutions or fixed answers, but marks roads to them. Design methodology is a process of design, expressed with the general condition of experience in architecture, furniture design and shaping.

2.2 The Principles of Universal Design

Universal design has practical and aesthetic values. The principles of universal design are defined as a philosophy of designing space which meets ever- changing needs of all individuals and families regardless of their age, size, physical advantages and physical limitations.

They produce qualities such as:

- Housing compatible for physically handicapped persons and their families.

- Residential areas which would be suitable for long- term housing, so people will not be forced to move out when they age or lose mobility.

"The seven principles of universal design" may be applied to evaluate existing designs, guide the design process and educate both designers and consumers about the characteristics of more usable products and environments.

1. **PRINCIPLE ONE: Equitable Use.**
2. **PRINCIPLE TWO: Flexibility in Use.**
3. **PRINCIPLE THREE: Simple and Intuitive Use.**
4. **PRINCIPLE FOUR: Perceptible Information.**
5. **PRINCIPLE FIVE: Tolerance for Error.**
6. **PRINCIPLE SIX: Low Physical Effort.**
7. **PRINCIPLE SEVEN: Size and Space for Approach and Use.**

Table 1. *Designing guidance based on a broad compilation of ergonomic resources.*

	Checklist	**Features**
1.	Adaptable design.	- The design should accommodate not only wheelchair users, but also their family members. - The height controls of kitchen appliances should be easy to reach.
2.	Safety-oriented design.	- The design should provide safe features and isolate or shield hazardous elements.
3.	Supportive design.	- The design should be used efficiently and comfortably with minimum efforts. - It should be designed for wheelchair users to store things at ease.
4.	Accessible design.	- The kitchen model should be created for people in wheelchairs to access it easily. - Kitchen cabinets and counters should be placed within the reach of wheelchair users.
5.	Aesthetics.	- The appearance of kitchen model should not be different from the kitchens which general people use. - The design should be harmonized with the interior where the kitchen model is located.
6.	Cultural / regional considerations.	- The design should reflect the specific dietary life of people.
7.	Cost.	- The kitchen model should be produced at an affordable price.

3. DESIGNING UNIVERSAL KITCEHN MODEL

3.1 Anthropometric analysis of the target group related to dimensioning of universal space for food preparation

The represented kitchen model is made by combining the design concept with major findings of former studies and universal design principles. The wheelchair dimensions are key measures for this universal kitchen space design. Also, anthropometric measures are important for proper sizing of the given project, which covers the border area between human bodies and various components (furniture and equipment) from the interior of the project.

We use two basic types of anthropometric dimensions: structural and functional, as starting point in designing a universal kitchen space. Structural dimensions are called static dimensions and include measures of the head, torso and limbs in a normal position. Functional dimensions are called dynamic dimensions and include measures of the human body measured in different operating positions- standing, sitting or in motion when performing given tasks.

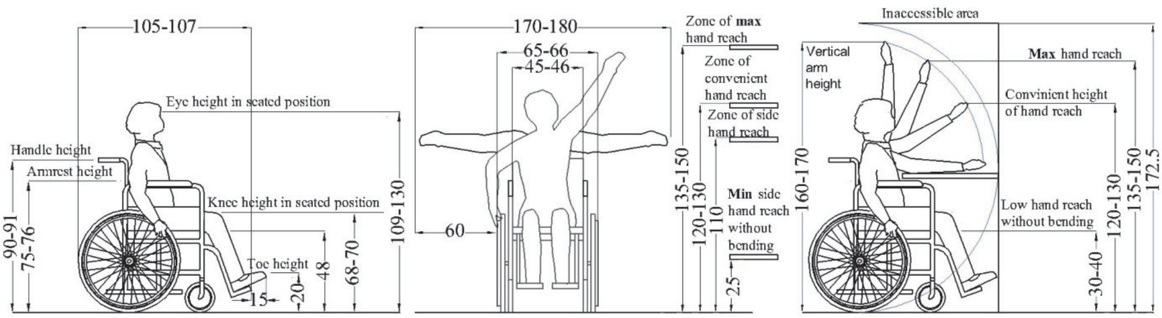

Figure 1. *Significant anthropometric measures and wheelchair dimensions for universal kitchen design.*

The overall wheelchair dimensions are 63.5 x 106.7 cm. An average person who sits in a wheelchair has front hand reach with dimensions of 38- 122 cm, measured from the floor. Optimal front reach of an average tall man moving with a wheelchair in the kitchen catches in height range of 40- 120 cm from the floor without bending. If there is an obstacle (for example desktop), the reach is reduced to maximum of 110 cm. Side hand reach while sitting in a wheelchair without bending is 40- 135 cm. If an obstacle appears deeper than 25 cm, then the reach is reduced to 115 cm. Dimensions from 0- 40 cm as lower and 120- 150 cm as upper reach limit are most suitable for designing kitchen elements. The design of the lower kitchen cabinets with knee space that provide wheelchair users easy access to desktop, is with open space of min 75- 90 cm wide, 70 cm in height and 45-50 cm in depth. Also important anthropometric factor is to provide enough kick space for the feet in a wheelchair, with withdrawal of the kick space base for 25- 30 cm in height and 15 cm in dept.

3.2 Functional analysis of the universal kitchen space (Spatial factors and ergonomic design measures affecting the universal kitchen model)

When exploring the relationship between dimensions of the human body and kitchen space (the table unit), sitting space around the table and space for horizontal communication and movement are the most valuable for interior kitchen design.

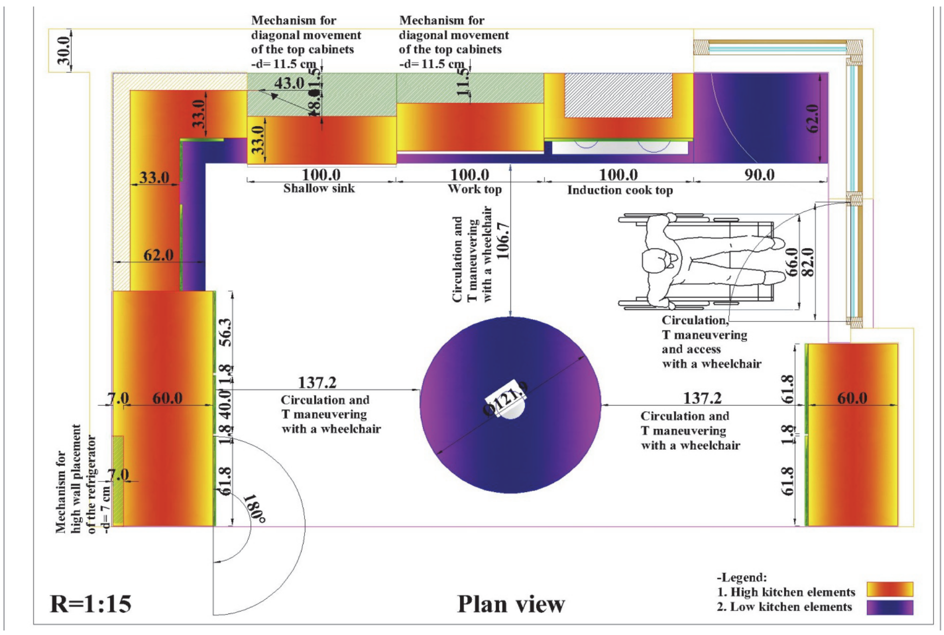

Figure 2. *Plan view of the presented universal kitchen model.*

The distance between the table edge and wall or other physical barrier must provide space for at least two of these elements: (1) space for wheelchair's manipulation ("T" maneuvering), (2) maximum width space for passage of one man in a wheelchair and one physical able man and (3) space for access the dining table with wheelchair.

The table design takes into account width of 61 cm which would allow sufficient space for maximum width of body in a sitting position with open elbows and common area in the center.

3.3 Interior circulation in the universal kitchen space

Required width of 91.4 cm provides partial circulation in the kitchen space, with a wheelchair in two paths. Width of 137.2 cm allows physically capable individual to walk despite the wheelchair, also that space is suggested to approach the table with a wheelchair and a person standing behind or preparing food in the kitchen area. Wheelchair users can maneuver 360° in space with a width of 137.2 cm, with round movement around the right wheel of the chair. Access width of 106.7 cm is required to accommodate a person standing beside the wheelchair.

The wheelchair user needs space for side reach of the kitchen worktop surface (the kitchen working area). The path for horizontal maneuvering needs to be with minimum width of 86.4 cm and food should be set at maximum hand reach of 50.8 cm on the worktop.

The approach to the door when it opens inwards, as the balcony door shown in this case, should be with 120 cm width for direct access to the door and opening angle of 90º. Space of 152.4 x 152.4 cm is suitable for disabled users to maneuver a wheelchair and open a door to get out. Wheelchair can also be maneuvered in an area of 121.9 x 121.9 cm, but this dimension is extremely narrow and should be understood as absolute minimum. Door width of 91 cm is considered as optimal space for passage of wheelchair users.

For easy use by persons in wheelchairs, windows should be mounted in the wall at a height not higher than 130 cm. They should provide sight view through in a sitting position.

4. ANALYSES OF SPACE, ITEMS AND EQUIPMENT OF THE KITCHEN MODEL FOR PERSON WITH DISABILITIES

The presented "**U**- shaped" kitchen model for physical disabled people and wheelchair users is developed with applying the principles of universal design. The layout of the kitchen is organized into six basic areas: food storage, kitchen- items storage, food preparation, cooking zone, dish cleaning and food consuming zone. Each work area provides a choice of work heights appropriate to tasks performed while sitting or standing and should provide space for people working together on a task. The variety of working heights is achieved by using adjustable mechanisms integrated in the kitchen elements or with additional pull- out work surfaces, set few cm lower than the countertop. The food preparation area is connected to the cooking area with a continuous counter top, which permits sliding of prepared items between the two.

Figure 3. *Presented "U- shaped" universal kitchen model with mechanisms for height adjustments of the kitchen elements.*

Spatial- organizational analysis of the kitchen model should adequately equip the premises and items for people with special needs in accordance with predefined anthropometric needs of the people who use them and provide clear space between all opposing cabinets, countertops, appliances or walls to permit a full turn by a wheelchair user. The goal is to achieve smooth flow of operations in the kitchen working triangle.

4.1 Kitchen zones and equipment

Figure 4. *Legend with design details of the presented "U- shaped" universal kitchen model*

*All base cabinets are projected with a kickboard placed 10 cm inwards, which provides toe or kick space with 20 cm height (higher than traditional height).

* In the kitchen construction are used hinges and mechanisms for easy touch opening and closing of drawers and doors. (Inside the kitchen elements is easy available in a sitting position).

Table 2. *Design details of the presented universal kitchen model.*

No.	Kitchen zones with equipment	Features
I.	"Consumables" zone	
1.	Built- in refrigerator for cold food storage	- dimensions: 60 x 60 x 160 cm - internal shelves with full pull- out extension - door hinges with full opening angle of 180° - installed on platform raised 22 cm from floor - built in cabinet high 212 cm
2.	High pull- out element integrated in the kitchen cabinet for dry food storage	- width: 40 cm - storage space - easy touch opening - full pull- out extension guides and rotation of 90° - integrated in cabinet high 212 cm
II.	"Non- consumables" zone	
3.	Top cabinets	- height x internal depth: 70 cm x 33 cm - storage space - easy touch opening - project placement at a height of 142 cm measured from floor to the lower element surface - integrated lift mechanisms for diagonal height placement adjustment - variable height placement, adjustable in continuous range of 43 cm downwards and 18 cm forwards (min 99 cm height from floor in the max forward position) - sensitive touch sensors integrated in the lower surface for lift possible stop - integrated task lighting under counters
4.	Top corner cabinet	- project placement at a height of 142 cm measured from floor to the lower element surface - storage space - easy touch opening
III.	"Cleaning" zone	
5.	Dishwasher	- dimensions: 54.5 x 54.5 x 45 cm - small capacity - internal shelves with full pull- out extension - front placed touch controls - located in the pantry at table height - raised 67 cm from floor
IV.	"Preparation" zone	
6.	Base corner cabinet	- drawers with full pull- out extension - storage space - drawers with easy touch opening - projected worktop height 85 cm from floor
7.	Base cabinet with integrated sink and cook top	- total height of 18.2 cm - total depth of 62 cm - projected worktop height: 85 cm measured from floor (normal position) - drawers with full pull- out extension - easy touch opening drawers - lift mechanism for worktop vertical height placement adjustment in continuous range from max 95 cm to min 65 cm height measured from

		floor, in continuous changing position intervals of 10 cm - additional roll- out worktop shelf made of fireproof material set under cook top, 3.2 cm lower from surface - open lower space for knees and wheelchair access with variable height adjustable from 47 cm to 77 cm measured from floor - button controls for lift mechanism mounted on the cabinet front
8.	Stainless steel sink	- shallow sink bowl - dimensions: 61.6 x 52.5 x 12.7 cm - the battery is placed 58 cm from the front edge of the worktop
V.	“Cooking” zone	
9.	Induction cook top	- provided visually distinct "burner" areas - 45 mm in thickness - cook top surface 91.5 cm x 53 cm
10.	Range hood integrated in the top cabinets	- installed in the top cabinet - operated with remote control
11.	Base cabinet	- drawers with full pull- out extension - drawers with easy touch opening - storage space
12.	High kitchen cabinet with integrated wall ovens	- drawers with full pull- out extension - drawers with easy touch opening - storage space - roll- out worktop shelves under wall ovens made of fireproof material
13.	Wall ovens	- raised 59 cm from floor - middle oven grid is at a height of 86.5 cm measured from floor - doors opening on vertical axis - internal shelve with full pull- out extension - front mounted burners controls
VI.	“Food consuming” zone	
14.	Round table	- diameter: 121.9 cm - projected worktop height: 85 cm measured from floor (normal position) - lift mechanism for worktop vertical height placement adjustment in continuous range from max 95 cm to min 65 cm height measured from floor, in continuous changing position intervals of 10 cm

5. DISCUSSION AND CONCLUSION

5.1 Effectiveness of the major kitchen elements

1) “Consumables” zone:

Increased opening angle flap of 180º improves access to the interior of the fridge for disabled people who use wheelchairs and other medical devices for movement.

Accessibility is facilitated by extraction with full extension shelves, as well as its height position. The refrigerator is raised to a height of 20 cm from the floor, which interior is in the range of eye height in a sitting position from 80- 87 cm.

High dry storage element for food with a full pull- out and rotation of 90º, achieves visual inspection and increased accessibility of sorted items, as well as wheelchair users can take out items without bending.

2) "Non- consumables" zone:

The lift mechanism allows the storage in the wall cabinets to be lowered to a more easily accessible height in seated position, with no loss of cupboard space when the unit is folded downwards.

Wall elements are placed in normal height of 142 cm, corresponding to a vertical reach of hand of 185- 195 cm while standing. The internal width of these elements is 33 cm, which makes it available for use.

Figure 5. *Vertical height adaption of kitchen elements and round table.*

3) "Cleaning" zone:

Raised platform makes dishwasher reachable in seated position, as well as obtains drawers space under the machine suitable for delay, within easy reach of seated people.

Dishwasher is raised at height 67 cm from the floor, which mean grid with full extraction is situated at a height of 89 cm, which is in the range of height vertical reach of the arm in a sitting position from 125- 130 cm and height of the eye in a sitting position of 80- 87 cm and the space under the machine is used for drawers suitable for delay. The door of the machine is a small size making it easier manipulation vessels and is facilitated parallel access with a wheelchair.

4) "Preparation" zone:

Projected worktop height of 85 cm of base cabinets is in range of vertical hand reach of max 130 cm in seating position without bending, short people and children.

Sink and battery are anthropometric positioned from the front worktop edge for easy forward reach in a sitting position.

Shallow sink allows its installation in kitchen element with open space for the knees and wheelchair access, which allows a resident to work in a seated position.

Lift mechanism for worktop vertical height placement adjustment is being useful for wheelchair users and people with a short stature and children as well as general people.

The open space for knees under the element provides sufficient space so that wheelchair may partially enter below the lower surface of the element and have comfort at work while seating.

The sink is related to the cooking zone with work surface that provides continuity in the kitchen work.

5) "Cooking" zone:

Smooth cook surface allows pots to slide from hot cook surface to cold worktop, which makes it easier for those with limited strength lifting, as well as wheelchair users and enables the surface to be cleaned easier than other cookers in seated position and reduces the risk of burns and fire.

Furthermore, thin cook surfaces allow designing lower kitchen cabinets with small thickness and open under counter knee space for wheelchair users.

Visually distinct burner areas of the cook top and front positioned control panel buttons aid proper visually uses especially for disabled people in wheelchairs, because of reduced range of vision in seated position. Wall ovens set into the high kitchen cabinet at a height of 59 cm in the range height of the vertical reach of arm in a seated position from 125- 130 cm and height of eye seated 80- 87 cm suitable for reach and door opening around vertical axis, thus allow easier access to the stove and reduces reach required to remove hot items from the ovens to wheelchair users and those with limited lifting force.

Figure 6. *Pull- out worktop shelves with full extension under wall ovens.*

The pull- out worktop shelves under the cook top and wall ovens provide landing pads for hot food that has been moved from the cook top or the ovens and facilitates the access of seated users including people in wheelchairs. Advantage is their manufacture of fireproof material.

6) "Food consuming" zone:

The dining table is easily moved and provides wheelchair- accessible knee and toe clearance. When designing the round table is taken into account the space of 61 cm which allows enough space for the maximum width of the body in a sitting position with widen elbows, while the common area in the center is limited. The round table is designed with diameter of 121.9 cm, on which are sitting four people in wheelchairs, with enough space for maneuvering around the table. Space from the floor to the lower surface of the table is a critical distance which provides enough room to approach a man in a wheelchair and is with installed height adjustment mechanism in height range of 65-95 cm, measured from the floor to the upper surface of the table.

Full- extension of the pull-out drawers and worktop shelves base cabinets achieve easy access to storage space without bending.

Front- mounted controls on all appliances allow person to work while seated and are easier to reach without bending from seated position.

The oversized push- button controls are on the cabinets' fronts and are mounted at a height that allows hand- eye coordination from a seated position.

Circulation in space:

Provided parallel approach to the dishwasher combined with a front approach to the counter with sink, serves wheelchair users and those who use rolling walkers. Edge of the round table from the edges of the kitchen work surfaces is presented with width of 106.7 cm to 137.2 cm, which represent horizontal path circulation, access to work areas and maneuvering space for wheelchairs in the kitchen. In front of the balcony door is provided pure spatial dimension of 137.2 x 137, 7 cm for "T" maneuvering of the wheelchair.

In the presented kitchen model is used one winged door with clear width of 82 cm, which corresponds to the minimum acceptable width for wheelchair circulation.

Windows with dimensions of 90 x 110 cm, allow natural room lighting on the kitchen workspace. They are set at 100 cm in height from floor, with the position of the handle which allows acceptable reach opening, closing and locking the window from seated position.

Interior lighting and interior colors:

The ceiling of the kitchen is designed with sunroof, which allows natural light in the room.

Distinctive and contrasting colors between the working surfaces and front surfaces (faces) of the kitchen elements, clearly define the separate working zones of the kitchen. The floor is visually contrasting with the kitchen elements colors, without shiny surface made from no slide materials.

5.2 Critical points in the universal kitchen model

Opening knee- spaces as well as lowering counters reduce the shortage of storage space, as well as, for tall people may appear not to be convenient.

The smooth surface induction cook- top has the disadvantage of having less capacity to catch spilled liquids, which may increase the risk of burns for someone sitting near it, this problem should be solved.

While placing a pull-out table under the cook top appears to be useful, more study should be done to find out its best location to maximize its usability. As suggested in the evaluation process, placing it to the right or left side of the present location should be considered.

In conclusion universal kitchens should be designed in accordance with the following questions:

- Whether the product can be used from a sitting position?
- Can the product be used without leaning over half?
- Whether the product requires reaching above the shoulders or below the waist?

However, it should be accent that objects designed as a universally accessible for persons with disabilities can exhibit many features of universal design, but often specifically designed to address specific disabilities or abilities this way not "universal." features "available items" should be critically evaluated to determine that the subject is useful to a wide range of people for which it is intended.

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STRENGTH OF FIXED CORNER JOINTS IN CABINET FURNITURE

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ABSTRACT

The objective of this work was to determine the strength of fixed corner joints, and to determine the finite element model (FEM) that can be applied for analysis of cabinet joints. For the purpose of constructing samples, three mostly used angled joints were applied, dowels, biscuits and groove joints. All groups of joint were made on plane and slope collision. The assessment of suitability of FEM in the analysis of cabinet furniture was made by comparing the values of joint strength obtained experimentally, with the one obtained by FEM. The main results of the examinations showed that FEM can be used for analyzing cabinet furniture, and FEM can predict the stresses and strains, as well as strength of joints used in cabinet design, which significantly shortens the time needed for development and analysis the of product structure.

Key words: cabinet furniture, joints, strength, FEM

1. INTRODUCTION

One of the preconditions for achieving optimal furniture design is the rationalization of material consumption, while maintaining the durability of the structure. The durability of structure depends on the properties of the base material from which the elements are made, but also on the choice of joints and their strength. Furniture design lacks of sufficient precise data related to dimensions of individual parts, and dimensions and strength of individual structural joints. For these reasons, during process of defining the structure, the designer is directed to his own findings, which are based on the experiences from traditional craftsmanship and engineering practices and the use of prototypes to determine the load bearing possibilities of joints and each individual element of construction.

One of the possible approaches to overcome this problem is the application of finite element method (FEM). FEM is numerical method designated for solving large number of engineering problems. The main objective of this method is to obtain a response of a physical system to certain conditions by performing simulations on a model that represents a simplified form of real object. By development of FEM the definition of structure is facilitated, thanks to the possibility of examination of model behavior in the load bearing conditions without destruction. This method has found its full application in mechanical and civil engineering. The interest of researchers for using the use of FEM in process of defining furniture structure was sporadic. Regardless the number of studies that shed light on problems in this area, the introduction of FEM in the furniture industry is still at the very beginning. There are few papers that analyze the factors affecting the strength and durability of cabinet furniture by the means of classical analysis or by FEM.

Smardzwski i Dziegielewski (1993) examined the influence of the type of back and the manner of its fastening to the rigidity of cabinet furniture. They used the back made of HDF. Based on the results obtained experimentally as well as by FEM the correlation between examined factors and rigidity and durability of cabinet furniture construction was established.

Cai and Wang (1993; 1995), analyze the strength of the corner joints in cabinet furniture and gave the recommendation for the linear structural analysis of cabinet furniture with the use of the FEM. In

their work, joint elements are defined as semi rigid based on their reduced elastic properties, and the recommendations for modeling with reduction of elasticity module of joint are given.
Although this approach gives good results from the point of deflection, concentration of stress that emerges in the joint environment does not correspond to the state of the real model.

Nicholls i Crisan (2002) offered a new approach to modeling the joints for cabinet furniture.o. Joints are defined as elastic elements that can accept and transmit torsion load. The analysis is conducted on one fixed and one detachable joint anchor and a minifix cam joint. The properties of finite elastic element were determined experimentally. Contrary to the works of Cai and Wang, the virtual model corresponded to real object.

During exploitation, joints in cabinet furniture are exposed to the forces and moments of different intensities and direction, as showed on the Figure 1.

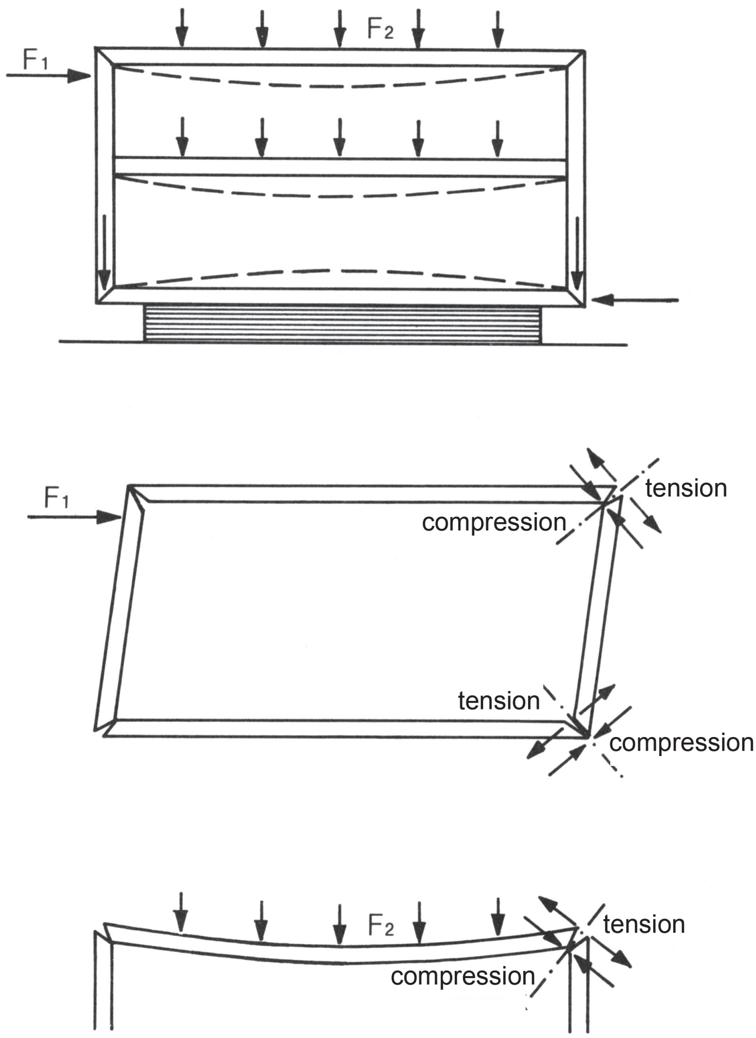

Figure 1. *The load of joints in exploitation*

Based on previous research (Eckelman, C.A.(1966), Gustafson, S (1995,1996,1996,1997,1999)), and experience from the practice, the strength of fixed joints in cabinets depends on the following factors: type of joint, gluing surface, machine accuracy, type of fitting, type of material, material moisture, quality and type of adhesive and gluing regime. In this work, type of joints and gluing surface were varied while all other factors remained constants.

The objective of this work was to determine the strength of fixed corner joints on the plane and sloped collision by experiment, and to determine the finite element model that can be applied for analysis of cabinet joints. The assessment of usability of FEM in the analysis of cabinet furniture will be made by comparing the values of joint strength obtained experimentally with the one obtained by FEM.

2. MATERIAL AND METHODS

Particleboard is one of the mostly used materials in the production of cabinet furnuiture. . For the purposes of this investigation, 19 mm thick three layer melamine faced particleboard was used (produced by Kronošpan). According to the technical specification of the manufacturer, the particleboard belongs to Formaldehyde Class class E1. The cuttinng of particleboard was done randomly in order to create experimental conditions which correspond to situation in regular production.

For the purpose of samples joining together, three angled joints that are mostly used were applied: dowels, biscuits and groove joint. All groups of joints were made on plane and slope collision. Within the each group 20 samples were made, which in total, for the whole testing, gives hundred and 20 samples. Machine accuracy and type of fit for all types of joints was controlled after machining and before gluing of samples. According to DIN 98100 all joints were made in TD40 machine accuracy class, with the type of fitting K/p. Dimensions of joint elements were measured by digital caliper, with accuracy 0,01 mm. Dimensions of samples and joints are presented in Figure 2.

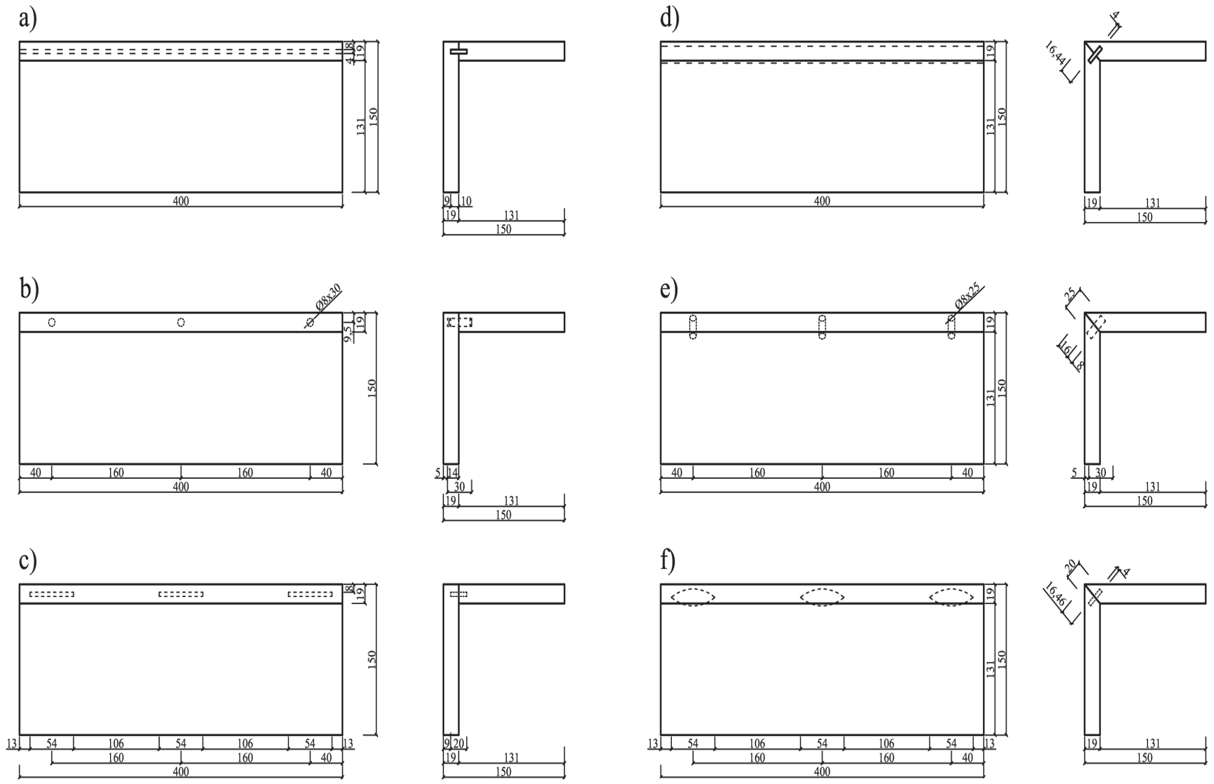

Figure 2. *Dimensions of samples and joint elements: a) groove joint with inserted feather on plane collision, b) dowel joint on plane collision, c) biscuit joint on plane collision, d) groove joint with inserted feather on slope collision, e) dowel joint on slope collision f) biscuit joint on slope collision.*

The gluing of joints in final wood processing was mostly done by PVA-c adhesives. In this research Titebond All-purpose White PVA-c glue, with following characteristics was used: Solids content is 46%, viscosity 6,500 cps, ph value 4,8.

Joint elements on plane and slope collision were produced on numerical centre. Before assembling the samples, of sample parts, adhesive was applied manually both on the hole and the plug.

Spreading of glue on surfaces was controlled while the amount of applied adhesive was not controlled. Clamping of samples was done on the vertical frame press.

Biscuits and inserted feathers were made of beech plywood with thickness of 3,2 mm, while the dowels were made of beech solid wood. After gluing, samples were conditioned for 15 days at room temperature of 20±2°C and relative humidity of 50±5%. The strength of joints was tested on the test machine-Tira test 2300. Loading pattern of samples is showed on Figure 3.

In accordance with the purpose of this work, respective models were formed which were analyzed by FEM. In order to determine the tension and deformities in joints, The FEM was used to form six different models which geometrically correspond to created samples. The sample joints were modeled as firm with no gaps between the hole and the plug.

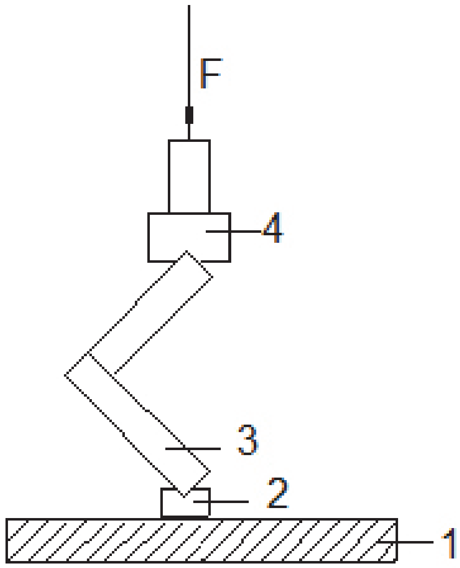

Figure 3. *Loading of sample*

In order to simplify the model the number of finite elements was minimized by defining the length of individual element within the contour of the board. Afterwards, the, automatic generation of the tetrahedral finite elements mesh was carried out. To obtain more accurate results the finer mash of finite elements was defined on the places were maximum stress was expected to occur: in joints and in position of loads application, Figure 4.

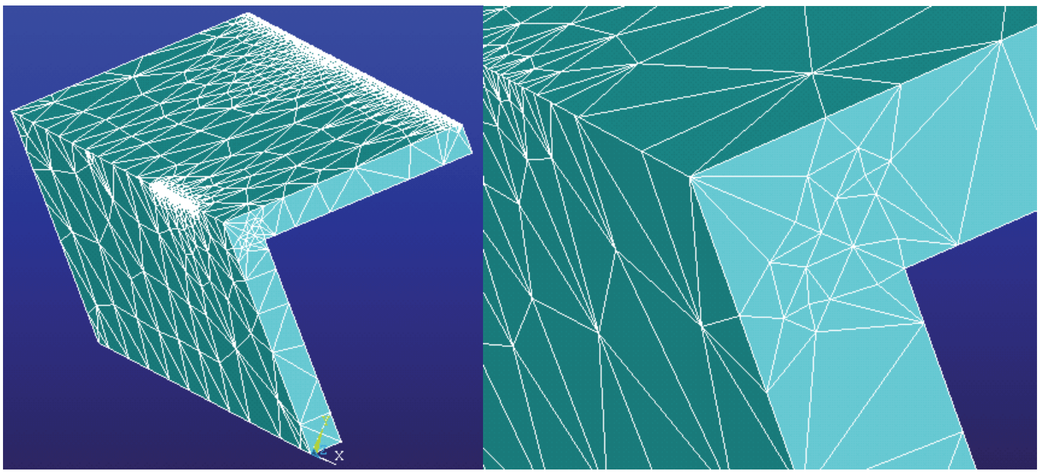

Figure 4. *Meshed models on the biscuit joint on slope collision*

The edge of upper board parallel to x axis was altered to surface in order to specify loads and boarder conditions more accurate and more easily. The formed surface had 400 mm^2, Figure 5. The values of loads applied on the models correspond to the average values of breaking force from the experiment.

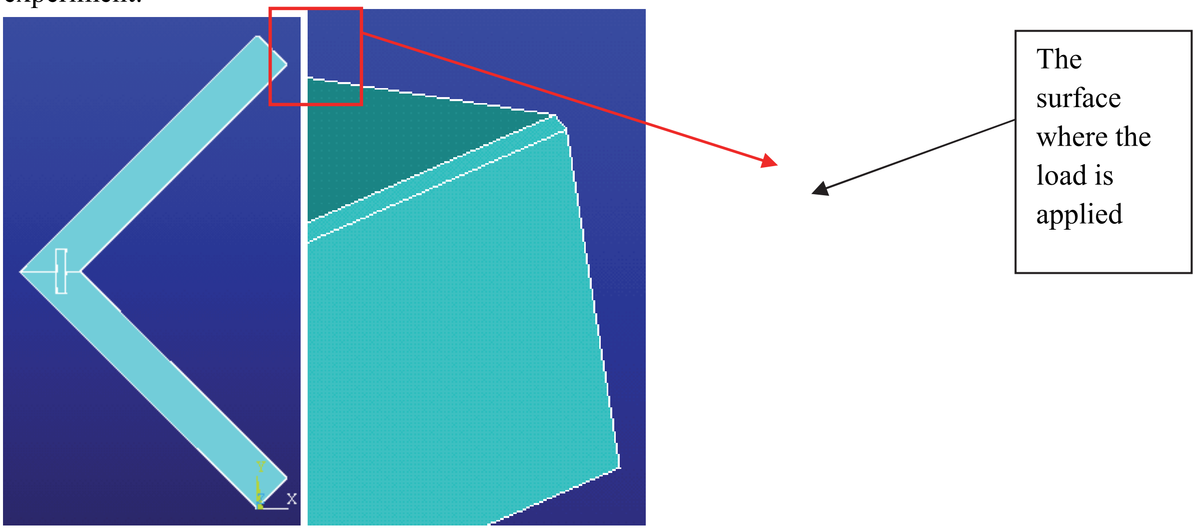

Figure 5: *Orientation of the model and formed surface used for the application of load*

3. RESULTS

Test results of tension strength of joints, obtained by experimental analysis, are shown in Table 1.

Table 1. *Test results*

	Joints on plane collision			Joints on slope collision		
	groove joint with inserted feather	**dowel**	**biscuit joint**	**groove joint with inserted feather**	**dowel**	**biscuit joint**
	[N]	[N]	[N]	[N]	[N]	[N]
$\overline{F}$	**1042.31**	**408.1**	**461.07**	**1385.17**	**1659.85**	**1525.45**
σ	363.35	113.7	68.98	430.09	841.38	56.9
V (%)	±34.86	±27.86	±14.96	±31.05	±50.69	±3.73

The value that was registered during experimental measurement of tension strength of cabinet joints corresponds to the force that led to loosening of glue in joints. In all samples there was an open gap at the outer (tensile) side of the joint. Wholesale distribution of results within the individual groups may be attributed to the uneven properties of particleboard. The results obtained by analysis using FEM are shown in Table 2. The table also shows the values of the pressures that were applied during the load of each model, and the values obtained by Von-Misses stress-es.

4. DISCUSSION

Based on the experimental results the following can be said:

The dowel joint on slope collision showed the greatest value of tension strength.The average value of joint strength was 1659.85 N. Joints on slope collision showed higher bond strength values than those derived in a plane collision. This difference was particularly evident in samples where the joining was done by using dowels and biscuits .

The strength of dowel joints with the plane collision makes is about 25% of the strength of the same element built on the slope collision. The value of bonding strength, in samples where biscuit joint on plane Collision was used, is about 30% of the strength of the same element, but built on the slope collision. For samples where groove joint with inserted feather were used there is no significant difference in values of bonding strength between groups of samples on slope and plane collision. Strength ratio of different joints on slope collision is in reverse order than their ration in plane collision.

Table 2. *The values of the applied pressure and the obtained Von-Misses stress*

Collision type	**Type of joint**	**Compressive surface**	**Pressure (N/m^2)**	**The maximum values of Von-Misses's stresses (N/mm^2)**	**Von-Misses's stresses on the bonding line (N/mm^2)**
Joints on plane collision	**groove joint with inserted feather**	$400mm^2$	$2,6 \cdot 10^6$	24,6	11,1
	dowel		$1,02 \cdot 10^6$	36,1	15,8
	biscuit joint		$1,15 \cdot 10^6$	28,2	10,1
Joints on slope collision	**groove joint with inserted feather**		$3,46 \cdot 10^6$	26,4	11,7
	dowel		$4,15 \cdot 10^6$	32	12,2
	biscuit joint		$3,81 \cdot 10^6$	27,1	9,8

Figure 6 shows the values and distribution of Von-Misses stresses in the case of slope collision when the groove joint was used. Maximum stress value was $0,264 \cdot 10^8$ N/m^2 = 26,4N/mm^2. By applying an external load, which value corresponds to the value of mean fracture force, an open-gap on tensile side of specimen appeared. In this case, the maximum load is registered on the position of joint elements. This value is about four times less than the bending strength of beech plywood, from which the inserted feather was made. During loading of samples in experiment, loosening of joints appeared on the bonding line, while elements of joint stayed undamaged, so the measured value of tension strength can be considered as joint strength. From figure 6 we can see that the value of the Von-Misses-stress on the bonding line is about 11.7 N/mm^2.

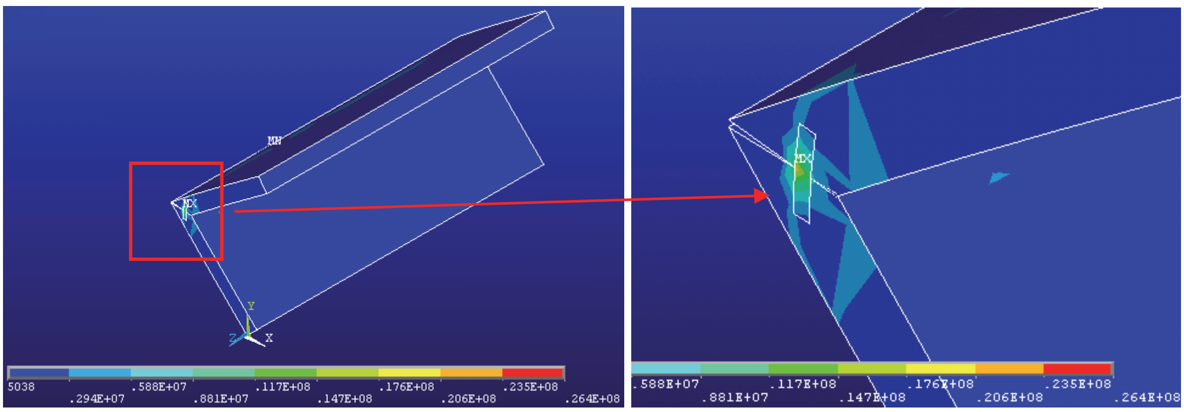

Figure 6. *Von-Misses-stress on the bonding line*

Based on research of Wehner and Brandle in Rosenheim (1983), (and presented by Albin (1991)), the maximum value of dowel pull-out strength from particleboard was 4.6 N/mm^2. In the case of the dowel on the plane collision, the vertical force that acts on the sample can be broken down in two components by means of statistic analysis, Figure 7. The force F2, which acts in the direction of the longitudinal axis of dowel, tends to pull the dowel out from the hole. By implementation the principle of stacking forces in the calculation, we get the value of pull out strength 3,74 N/mm^2, based on three dowels per length of sample. Compared to this value, the pull out strength of joints with dowel on slope collision is slightly higher (approximately 3,9 N N/mm^2 per dowel). In the case of joint with dowel on slope collision the direction of loading force corresponds to the longitudinal axis of dowel.

The values of calculated joint strength are lower that the one that Albin (1991) presented.

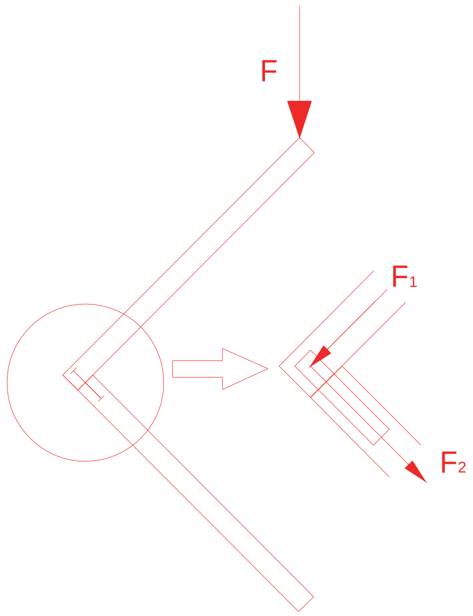

Figure 7. *Display of forces acting on the joint*

As part of their work, Vassiliou and Barboutis (2008) examined the strength of middle cabinet joints with biscuits. They found out that the middle biscuit joint (beech wood biscuit with dimensions 60x24mm) gives the average tensile strength of 1098.7 N. If we put these results in relation with the gluing surface we will get average value of the biscuit tensile strength of 2.3 N/mm^2. As the number of biscuits in this research was three, obtained the tensile joint strength of 3.3 N/mm2, which is for approximately 1 N/mm^2 higher than the values presented by Vassilou and Barbutis (2008). There are no data considering tensile strength of groove joint for cabinet furniture, that could be find in literature, as we are aware. So it was not possible to make comparison between experimental results and the results obtained by modeling.

5. CONCLUSION

- Based on the results of the examinations following conclusions can be made
- Dowel joints on slope collision shown the greatest tensile strength
- Values of Von-Misses stress, when dowel joints were used, are very close to the maximum values of tensile strength obtained by other authors. According to this result, The FEM can be used for analyzing cabinet furniture with dowel joint as joining element.
- The values of Von-Misses's stress, when biscuit were used as a joining element, were slightly higher than the maximum tensile strength values obtained by other authors.
- Due to the lack of data regarding the tensile strength of groove joints in particleboards, additional research are needed in order to make comparison with the results obtained with the FEM.
- FEM can predict the stresses and strains, as well as strength of joints used in cabinet design, which significantly shortens the time needed for development and analysis the of product structure.
- Out by the FEM simulations, which provides non-destructive assessment of loading capacity of furniture structure

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IMPACT OF ERGONOMICS IN DESIGN OF WORKSPACE

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ABSTRACT

Macedonian experience in applying ergonomics, ergonometric principles for design of workspace in order to achieve greater productivity and efficiency, are insufficient and approximate. Taking into consideration the great importance of this science, which is always based on the anthropometry of the human body on the one hand, and the measurements taken from the project design for the furniture and the interior on the other hand, it is a valuable tool in the hands of a furniture designer nowadays.

The ultimate goal is to get a quality workspace in which the human factor is very important. Through better understanding of the parameters of ergonomics, the designer can improve health and safety in the workplace. Actually, it is the designer's obligation and task to constantly monitor the developments in the field of ergonomics, in order to implement, maintain and improve the design of furniture. The paper includes the most common ergonomic problems of specific jobs and ways to overcome them.

Only by qualitative understanding of the human factor, his/her job, staffing, work environment and interactive relations that exist between them, will modern designers be able to produce healthy and safe designs, thus creating effective and productive working systems.

Keywords: ergonomics, anthropometry, human factor, workplace facilities, limits, staffing, work environment, interaction.

1. INTRODUCTION

Ergonomics is a scientific discipline that studies conformity of people with their immediate surroundings and considers the man a priority with regard to his capabilities and limitations. Applying ergonomics and its principles for the design of the workspace results in greater productivity of the employee. The example with Macedonia speaks about insufficient familiarity with the basic parameters of ergonomics and its influence on the development of quality relation between the furniture and its user.

In contemporary scientific sense, the consumer oriented design of products (furniture and interior) also depends on the quality of their mutual relation.

This paper's goal is to analyze this key issue with respect to planning the workspaces. Clarification, as well as better understanding of ergonomics, can improve the employee's health, the safety in the workplace and the quality of the work.

The subject of analysis is the administrative workspace with a special emphasis on the desk. Some aspects of ergonomic problems and examples are given, as well as effective guidelines about what to do and how to avoid them in future. The paper analyzes the qualitative connection between ergonomics and tasks, the equipment, the information and the surroundings, as well as the question of their functioning as a whole.

1. In order to evaluate the mutual influence of an employee and his/her work, ergonomics must take into consideration lots of aspects, such as:

- the way the work is done and the employee's demands
- the equipment that is used (size, shape, appropriateness with the task)
- the information used (the way it is presented, the approach, as well as modifications)
- physical environment (temperature, humidity, light, noise and vibrations) and social environment (such as the team work and the supportive managerial team)

2. Ergonomics takes into consideration all physical aspects of an individual, such as:
- size of the body and its shape
- adaptive value and force
- body posture
- senses (especially sight, hearing and touch) and
- muscles', joints' and nerves' efforts.

3. Ergonomics also takes into consideration the psychological aspects of the person:
- mental capabilities
- character
- knowledge and
- experience.

By evaluation of these aspects of people, the work, the equipment (the furniture) and the working environment (the interior), as well as the interaction between them, designers can design a safe, effective and productive working system.

2. ANALYSIS OF ERGONOMIC PROBLEMS WHILE DESIGNING OFFICE WORKPLACE

Ergonomic problems while planning the office workplaces can primarily appear while planning the furniture and the interior and can be analyzed in order to solve mainly physical issues, like:

- optimum height of the working surface, in order to allow adequate space for the employee's legs
- depth of the working surface in order to ensure optimum space for smooth work
- width of the working surface in accordance with the needs of the workplace, in order to ensure optimum space both for placing the stuff and for working
- dimensioning of the elements by the wall (built in or not), it is important for them to be easy to access regarding their width and depth
- ergonomic and anthropometric dimensions of the chair for the employee
- psychological and sociological aspects of the individuals in the workplace.

In addition, for example: huge or small amount of work, insufficiently clear tasks, time pressure, inadequate training and little support by the group, all these aspects can negatively affect the individual and the work he/she is performing.

The following examples underline some "typical" ergonomic problems that occur in the workplace related to the desk and the computer:

1. The screen is improperly placed, higher/lower/closer/further from the user or it is placed oblique to the user.
2. The mouse is placed too far and the user needs to stretch in order to reach it.
3. The chair does not fulfill the anthropometric and ergonometric standards for a modern way of working on the computer.
4. Chairs are improperly arranged to fit the employee, creating an odd and uncomfortable position;
5. There is gleam on the monitor caused by the light and windows from behind, increasing the risk of damaging the sight.
6. The hardware and/or the software are not suitable for the assignment or for the person using them, thus causing frustration and stress.
7. Not enough breaks and change of activities.

Bad body position, lack of adequate equipment and the ergonomically-addapted design of the working unit/table with a chair, can be factors that contribute to the inadequate working on the computer. You can see in the picture all the parts of the body which are considered to be critical points. Therefrom, key actions for improving the workplace follow:

- Ergonomic guidelines, but only those which are scientifically confirmed. Ergonomic studies should be based on facts, experiments, measurements, statistical comparisons, as well as the theory on using body mechanics as a basis.

- Beside the accuracy of these studies, there is no doubt that ergonomics is personal. What is suitable for someone's body does not have to be appropriate for ours too.

Figure 1. *Ilustration of the critical points on a human body with an ergonomically inappropriately designed workstation with a computer*

- The desk can not be imagined without a drawer for the keyboard or another appropriate solution for this important segment of a desk, and the drawer must be placed on a proper height.
- The keyboard should not be placed on the table, but on the drawer.
- The monitor should not be placed high above the head.
- The sitting position should not be stiff and straight.
- While sitting the body should not lean/bend forward.
- While working one should not stay for a long time in one position without occasional moving around. Frequent movements from the basic position make the employees more productive, healthy and without a danger of catching diseases. (for example a venous thrombosis, Cooper, C., et al.1994)

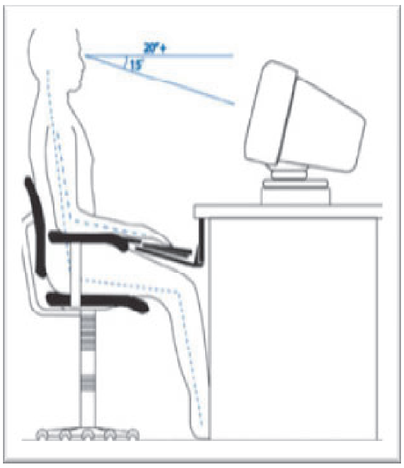

Figure 2. *Appropriate ergonomic placement of a computer monitor*

A computer user is in constant contact with five elements: a monitor, a keyboard and a mouse, a chair, the closest shelves for putting stuff and the source of light (natural and artificial). The development of a quality combination from ergonomic and anthropometric aspect will improve the comfort and efficiency and will also lead to preventing recurrent stress injuries, situations which every serious enterprise pays a good attention to nowadays (mainly because of the health and financial consequences both for the employees and the enterprise).

2.1 Monitor

- the monitor should be placed at a right angle against the sources of light (mainly the natural ones – a window) in order to minimize the reflection of light on the screen.
- place the monitor as far away as possible from the eyes, until it reaches a distance at which you can read/write without having to focus consciously. That means that the distance should be at a least 50cm.
- the center of the screen should be placed at 15 degrees (the bottom angle) from the user's eye; thus the neck is mildly bent and the head is positioned with right angle to the floor.
- the monitor, the keyboard/the mouse should be placed in one line.

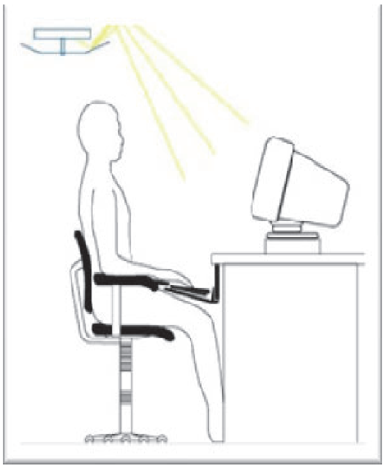

Figure 3. *Indirect artificial light in the workplace*

2.2 Light

- offices should be moderately lit with a light of 215-538 lux (which is corresponding to a beautiful, bright day when sunglasses are not necessary)
- lighting the screen or the keyboard with a direct light, attached to the unit itself, is not appropriate
- the best solution would be usage of both types of illumination (yellow and fluorescent light) because this approach creates an appropriate colour of light and work atmosphere and it decreases the flickering of the light sources.

Figure 3. *Ergonomically inappropriately placed keyboard*

2.3 Keyboard

- the keyboard should be positioned a little bit under the elbow height and at a negative angle so that the wrists could stay straight when the sitting is in an a slightly bent position.
- the wrist should not rest on the wrist rest while the person is actively typing. The aim is to rest the wrists while working and not rest on them. Palms, forearms and Upper arm should not be leant on at all while writing.

We should not lean on the keyboard in order to straighten out our back, nor should we place the keyboard inclined towards us (with the back part in a higher position than the front one). In some textbooks the position of a sloping keyboard (at a positive angle) is supported and considered suitable for the sightline, but that is wrong. The negative angle that allows the wrist to be in its natural position, as well as the veins in the arm, all this makes this position more appropriate, because when placing the keyboard at a positive angle to the position of the arms, this can lead to injuries as a result of a recurrent stress. (S. Pheasant, 2003).

The two most common injuries within this group are Carpal Tunnel Syndrome and tendons injuries. The Carpal Tunnel Syndrome is caused by a compression of the median nerve in the narrow arm channel that happens as a result of a repeated bent position of the hand and swelling of the surrounding tissues. In time this pressure can lead to serious consequences (S. Pheasant, 2003). The palm tendons injury occurs as an inflammation (Tendinitis), when tendon fibers separate and shred and consequently an intensified friction, a developpment of larger swellings and pain occur.

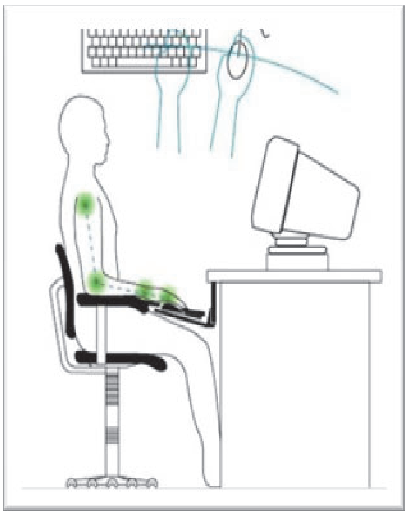

Figure 4. *Ergonomically appropriately placed mouse*

2.4 Mouse

- the mouse should be placed at the same height with the keyboard and right next to it.
- the position of the mouse should always ensure free rotation of the palm to the left and to the right.
- the hand should be relaxed when using the mouse and should not lean on it

3. FURNITURE ERGONOMICS CAN IMPROVE HEALTH AND SAFETY IN WORKPLACE

According to some studies in the USA (A.R.Tilley, 2002), average losses exceed 7300 USD per employee annually because of decreased productivity and sick leaves as a consequence of the unergonomic workplace. More than 50% of the injuries are related to injuries of the spine and because of that we should make sure that ergonomically designed chairs and desks are used. According to the studies (A.R.Tilley, 2002) after some time 80% of people have some type of back or neck injury.

The furniture should fulfill some ergonomic norms in order to improve health and safety of employees in the workplace. These norms refer to the chair and the desk that are directly and continually used by an employee. The paper focuses on the computer desk. Following the analysis, we will highlight twelve actions that should become norms for better organized ergonomic workplace:

1. Usage of only ergonomically designed chair (with all the parameters for spine and neck rest offered by contemporary manufacturers) (H.Drayfuss Associates, 2002);
2. The top of the monitor should be placed 5 to 8 cm higher than the height of the eyes.
3. There should not be any reflection on the monitor screen.
4. Facing the computer screen, you should sit at a distance of 1 cubit, which is the distance of the arm from the shoulder joint to the top of the middle finger of the hand (Aleksievska, X.J1985).
5. The legs and feet should be placed flat on the floor/or still better on the foot rest.
6. A documents' holder at a proper height above the desk should be anticipated for every workplace.
7. Palm and fingers should obligatorily be straight and open.
8. Hands and elbows should be put against the body.
9. The position of the monitor and the keyboard should be straight, in front and in the middle.
10. The keyboard should be mildly inclined backwards to the desk.
11. The working surface should be flat and stable, well attached and from a material that is easily maintained.
12. More frequent short breaks from work in order to change positions.

If we analyze the reasons for sitting we will come to some important conclusions. While sitting, if the body is perfectly positioned, we spend 20% less energy than while standing and doing the same work. In addition, the pressure of the spine in a sitting position and leaned back is for 50% lower than while standing. While sitting we can achieve better balance in performing some delicate motoric tasks. We can see from the diagram below how much and in which way the ergonomic sitting influences productivity (A.R.Tilley, 2002)

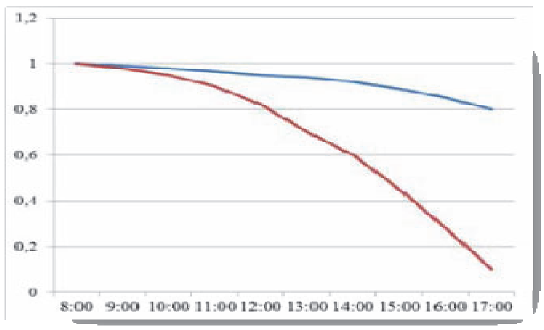

Figure 5. *Ergonomic sitting influences productivity in workplace*

Analyses of certain studies in the USA (H.Drayfuss Associates, 2002) have resulted in calculations that show how much a company can save and gain in productivity, only by replacing the unergonomically designed furniture with ergonomic, with special emphasis on sitting as the most common working position in a huge number of workplaces nowadays. On the diagram from Fig.5, an employee's productivity in common work conditions is presented with the lower line, and the productivity of an employee using ergonomically designed furniture and equipment is presented with the higher line. It is obvious that the highest productivity is achieved at the beginning of the workday when the employee has the most energy. As time passes by, productivity decreases until it reaches the lowest level at the end of the working hours.

Ergonomically designed furniture and equipment contribute to productivity by slowing down its decrease proportionally to approaching the end of the working day, which ultimately leads to better performance of the employees. (Papic, M.Z. et al.2012) Experts in the field of ergonomics generally agree that there is not one, uniquely correct static sitting position which should be constantly practiced. On the contrary, in almost all ergonomic studies, the need of frequent changing of the sitting position is particularly emphasized in order to improve the bloodstream and reduce the muscles' fatigue.Studies in the field of ergonomics and correct body position at a desk are clearly shown in the drawings, and therefore both positions are presented in the paper, correct vs. incorrect position, while sitting and working at a desk.

Figure 6. *Position of the upper part of the body, with usage of ergonomically designed chair that allows keeping the position straight.*

The head should be in a balanced position and in line with the spine. Inclining the head forwards or backwards during working for a longer period of time surely causes tension in the neck. The upper arms should be against the body and relaxed, i.e. they should not be stiff or bent forward or on either side.

Figure 6a. *Position of forearms and palms*

Palms should be at the same level as the elbows, small variances are tolerated but the arm rests should not obstruct the hands' movements and if so, their position should be adjusted.

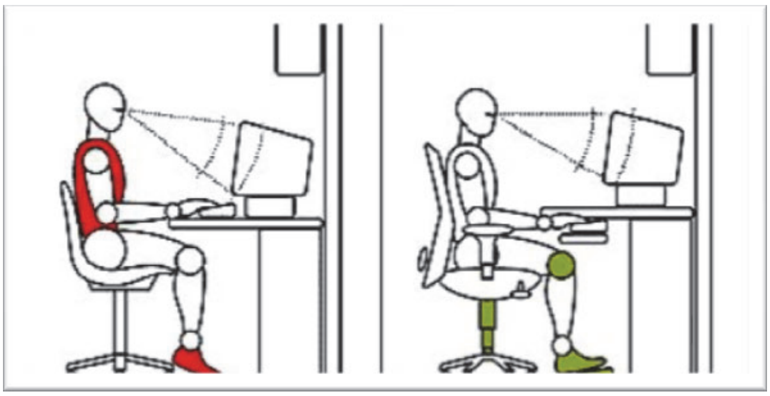

Figure 6b. *Position of feet and knees in relation to ergonomically, correct height of the sitting.*

Feet should be comfortably resting on the floor or another solid surface. If the chair is not height-adjustable, then a foot rest should be used. Regarding the height of the chair, a chair lifted too high or too low does not give good results in the long run. The correct height of the working chair varies nowadays, but with slight deviations, the most comfortable chair height would be the one of 47-48 cm (from the floor to the edge of the seat), with the possibility of making adjustments depending on the anthropometry of the person.

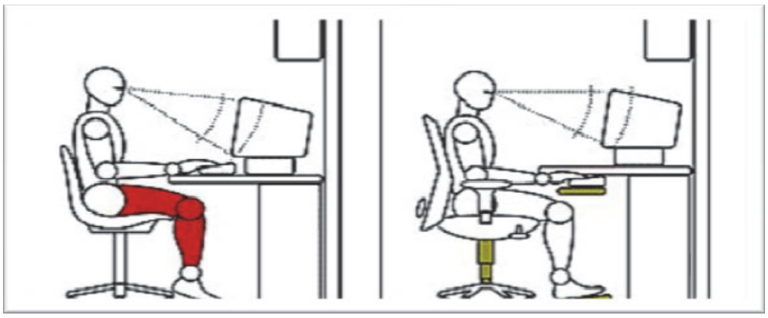

Figure 6c. *Usage of a keyboard drawer and chair height adjustment for better hands', palms' and legs' position.*

Feet should be placed a little bit ahead of the knees. For the legs' position it is important that the upper legs are not too tight on the soft seat of the chair, in order to allow better bloodstream in the lower limbs.

4. CONCLUSION

Ergonomically correct design of the desk, the chair and the associated equipment, as well as their correct dimensions, can be best comprehended on a drawing. Because of these reasons the conclusions in this paper are presented with drawings containing exact measurements and positions in the workplace, all based on the previous studies and cited references.

Regarding the physiological features of sitting positions and respective requirements for an anatomically healthy seat, i.e. the criterion for entirely correct sitting, we should take into consideration the impacts of social and cultural interaction, the physiological comfort of the person sitting, the formal and expressive characteristics of the model, the influence of the materials and the manufacture methods, the economy of manufacture etc. The extremely wide range of activities and situations that require a certain sitting position results into a variety of ways of sitting. Some sitting criteria are universally acceptable, while others vary depending on the way of sitting. Gradually it becomes substantially important to know which sitting ways are being considered when talking about sitting criteria. Because of the great interest in activities and the employees' health in diverse jobs, we are mainly concerned with types of sitting practiced in the working environment (such as in factories, offices, vehicles). But the positions and physiological criteria can be regarded the least changeable concerning the type of sitting, and therefore we can practice the following for almost every type of sitting model (with obvious exceptions for the seats for the disabled, the dental chairs, the wheelchairs etc.). However, it should be stressed that while the criteria remain the same, the modification of their dimensional and other characteristics comes with change of the type of seat.

Beside the simple "setting feet free from the body weight" (an advantage of the sitting position in comparison to the standing one), sitting on a chair has other positive aspects for the person working: thanks to the increased stability of the body (in comparison to standing), the capability of carrying out assignments that require preciseness increases, i.e. stable and nice manipulative movements are more possible. There are no more waves of fatigue while performing tiring tasks, since the muscles are partially free from their work, which is keeping the body stable. As the feet are free, they can be involved in the work and control the operations. Even when not working, the whole body can relax on an ergonomically appropriately designed seat. Accordingly, sitting becomes an important body position for the employee while performing his/her working as well as free time activities, apart from situations when whole body's agility is required.

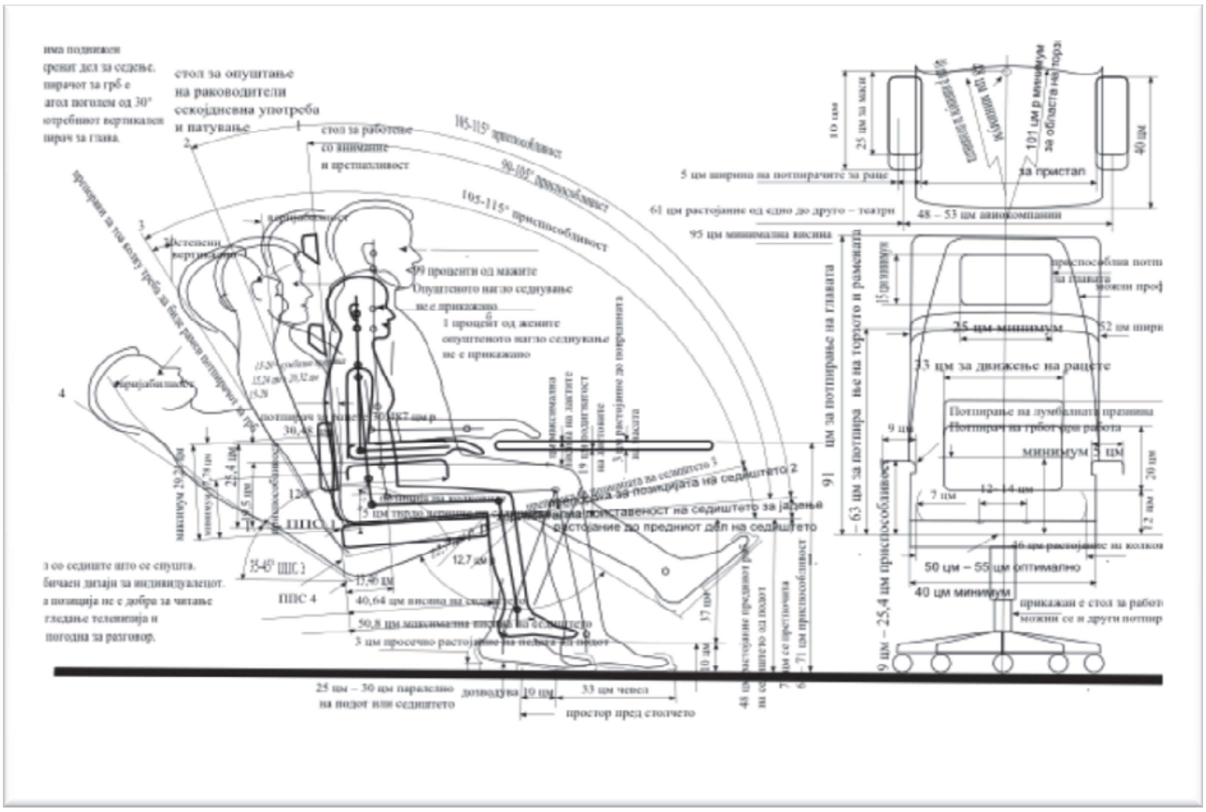

Figure 7. *Positions while sitting on a chair*

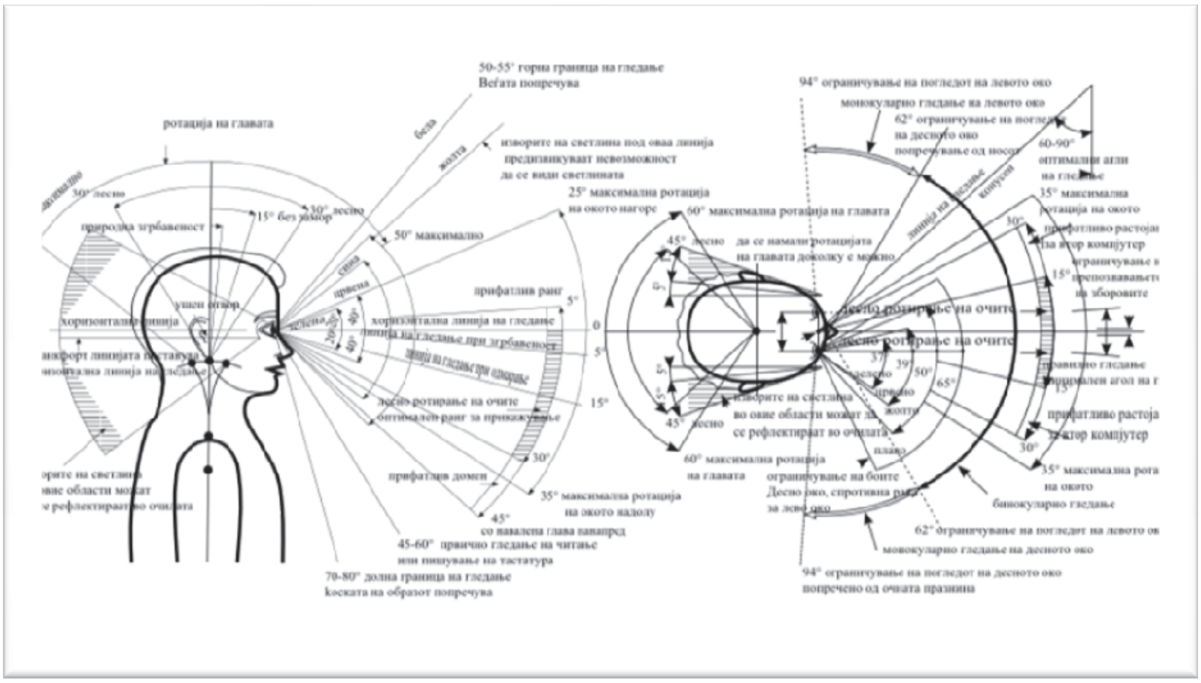

Figure 8. *Sightline, correct distance for writing, reading, optimal sightline and light impact on the sightline.*

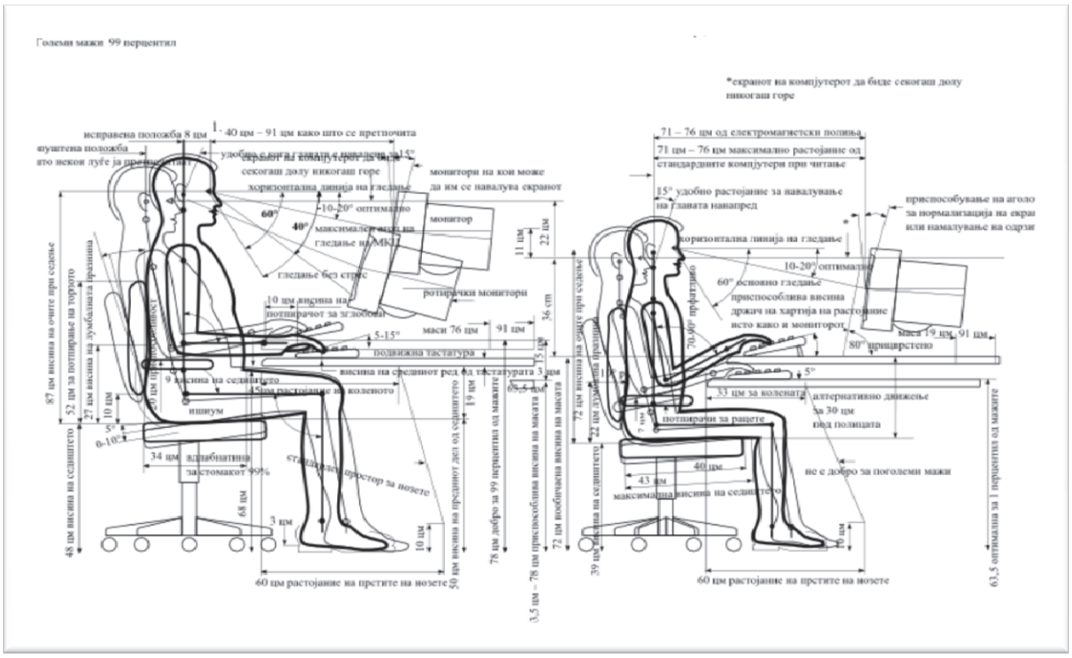

Figure 9. *Sitting positions on a chair for men with smaller and bigger build*

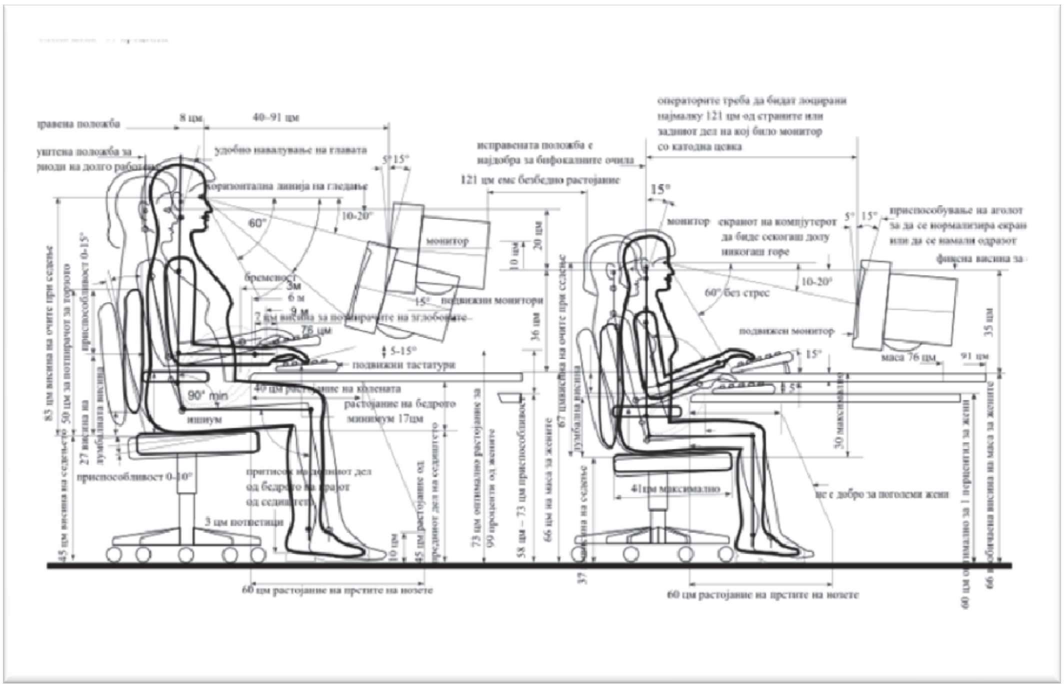

Figure 10. *Sitting positions on a chair for women with smaller and bigger build*

The application of ergonomics while designing office furntiure and the associated equipment allows:

- decreasing the risk of accidents
- decreasing the risk of injuries and diseases and
- improving the employee's performance and its quality

- Ergonomics can also decrease the potential for diseases at work. With good layout of the furniture and the equipment, as well as their arrangement in the way they are used the best, we can achieve harmony at work. Objects that are often used should be placed within hand reach, with no need of stopping the work, stretching or bending.

Good ergonomic solution for the workplace has great economic significance. Investing in ergonomics does not have to include high expenses and can save money in the long run, decreasing the risk of injuries and absences from work. Understanding ergonomics at your workplace can improve your daily work routine. It becomes possible to eliminate headaches, pain and stress in the workplace and to also achieve bigger work satisfaction. Ergonomic solutions can be clear and simple to use. Even small changes like modification of the chair height can make a huge difference.

Insufficient analysis and observation of the ergonomic principles can cause serious consequences, not only for the employee but for the whole organization, too. A great number of well known accidents could have been prevented if the ergonomic parameters had been taken into consideration while designing the furniture in the workplaces and the interior.

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INFLUENCE OF PLYWOOD STRUCTURE ON COMPRESSIVE STRENGTH PARALLEL TO THE PLANE OF THE PANEL

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ABSTRACT

The aim of the researches presented in the paper is to study the influence of the changes in plywood structure on plywood compressive strength parallel to the plane of the plywood panel. These changes relate to the change of the position of the layers in the structure of the panel around the central axis, without changing the number and the thickness of the veneers.

For studying this influence, four models of laboratory nine-layered plywood are made. The models are made from peeled beech veneers with thickness of 1,2; 1,5; 2,2 and 3,2 mm.

The modeling is made on the base of the changing of the position of veneers with thickness of 3,2 mm around the central axis (axis of symmetry).

Pure water-soluble phenol-formaldehyde resin is used as plywood binder.

The compressive strength parallel to the plane of the plywood panel is tested in two directions, parallel and perpendicular to the face grain.

The research results showed that all tested models of plywood meet and exceed the defined values of compressive strength in accordance with the requirements of the standard MKS D.C5.043 for structural plywood for use in construction.

Keywords: plywood, veneers, compressive strength, changes, position, layers

1. INTRODUCTION

Modern construction of wooden buildings today is unimaginable without the use of wood composite materials. The wide range of wooden composite includes materials for indoor and outdoor application and for structural or non-structural use. Plywood is one of the major types of wood composite materials for structural use.

In developed European countries and American Continent the use of wood composites in construction of wooden buildings is on a significant level. In North America, wood composite materials represent more than 40 % of the materials that are used in construction of residential buildings (Winandy, 2006).

The cross-laminated layup of layers of veneers gives plywood excellent strength characteristics, stiffness and dimensional stability. The form of these panels allows its application in many areas where materials in large formats are required. Plywood is utilized for many applications in constructions: as a part of engineered wood products (webs for wood-I joists), for siding, sheathing, flooring and roofing.

For use the plywood in modern construction a higher physical and mechanical properties are required to be achieved.

One segment of the researches of plywood as one of the most present materials in construction includes studying the impact of the structure of these panels on their properties. Making certain changes in plywood structure can improved the plywood properties. These changes refer to the change of the position of the layers in the structure of the panel around the central axis, without changing the number and the thickness of the veneers (Jakimovska Popovska, 2011). In such a way, by making certain laboratory plywood models by changing the position of the layers in plywood structure, some optimal plywood composition with improved physical and mechanical properties can be provided.

2. MATERIALS AND METHODS OF THE EXPERIMENTAL WORK

For realization of the research four models of laboratory nine-layered plywood are made. Each model has the same number of veneer sheets of each thickness class: tree veneer sheets with thickness of 3,2 mm and two veneer sheets with thickness of 2,2; 1,5 and 1,2 mm.

The modeling is made on the base of the changing of the position of veneers with thickness of 3,2 mm around the central axis of the panel (axis of symmetry). The central layer of each model represents a veneer sheet with thickness of 3,2 mm, oriented parallel to the face grain of the panel.

As in the first model the veneers with thickness of 3,2 mm are positioned next to the central veneer sheet, their position in the other models moves to the surface of the panel, so that in the fourth model these veneers are the surface layers of the panel (Figure 1).

The orientation of adjacent layers in plywood structure is at right angle, which means that the grain direction of the surface layers in all models is parallel to the longitudinal axis of the panel.

The panels are overlaid with phenol formaldehyde-resin impregnated paper with surface weight of 120 g/m^2 that is bonded during the hot pressing process.

Pure water-soluble phenol-formaldehyde resin with concentration of 47,10 % is used as plywood binder, spread in quantity of 180 g/m^2.

The panels are pressed in hot press using the following parameters: specific pressure - P=1,8 MN/m^2; temperature of hot plates - T=155ºC and pressing time - t=20 min.

Dimensions of the panels are 580×580×17 mm. The humidity of the panels is 8 %.

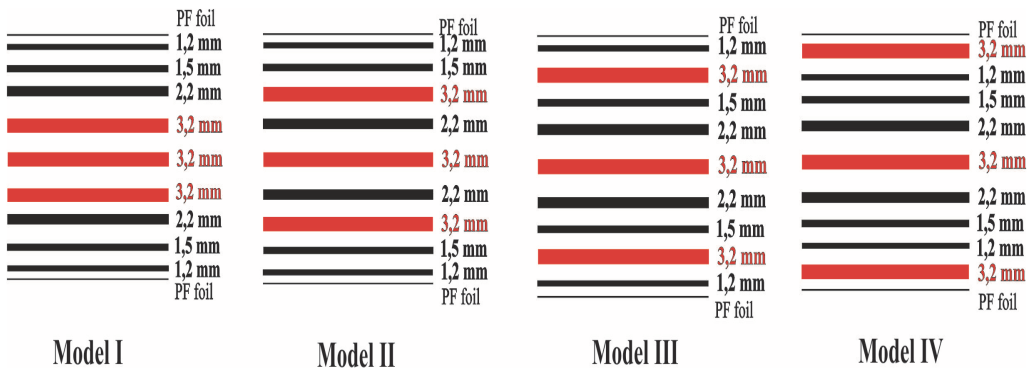

Figure 1. *Pattern of the models structure*

The denotations of the laboratory plywood models have the following meaning:

- **Model I** – nine-layered plywood in which the veneers with thickness of 3,2 mm are positioned in the fourth, fifth (central) and in the sixth layer of the panel (γ=761,70 kg/m^3);
- **Model II** – nine-layered plywood in which the veneers with thickness of 3,2 mm are positioned in the third, fifth (central) and in the seventh layer of the panel (γ=759,99 kg/m^3);
- **Model III** – nine-layered plywood in which the veneers with thickness of 3,2 mm are positioned in the second, fifth (central) and in the eighth layer of the panel (γ=782,34 kg/m^3);
- **Model IV** – nine-layered plywood in which the veneers with thickness of 3,2 mm are positioned in the surface layers and in the central layer of the panel (first, fifth-central and ninth layer) (γ=785,90 kg/m^3).

The compressive strength parallel to the plane of the plywood panel is tested according to the national standard MKS D.A8.070/85. This property is tested in two directions, i.e. parallel and perpendicular to the face grain of the panel (Figure 2).

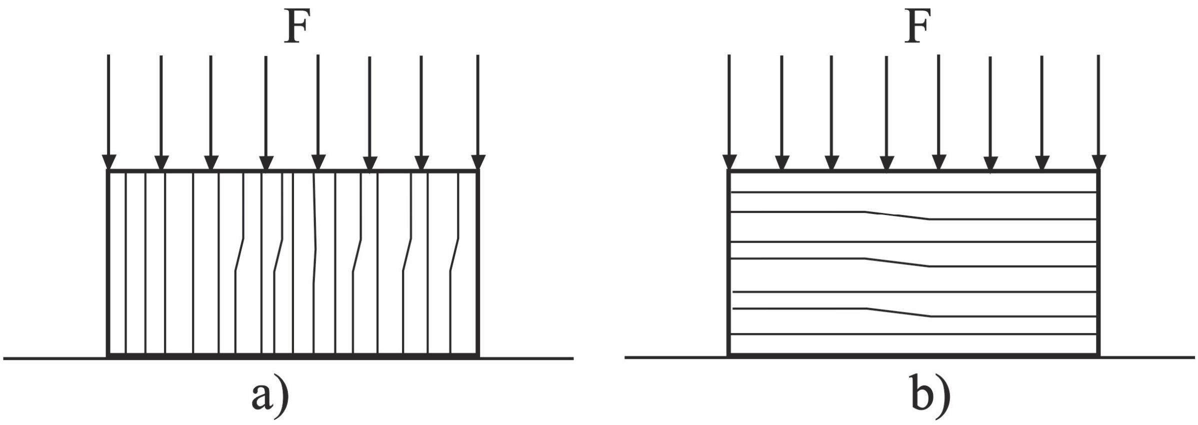

Figure 2. *Pattern of applying of pressure*
a-parallel to the face grain; b-perpendicular to the face grain

3. RESULTS OF THE RESEARCH

3.1 Results of testing the compressive strength parallel to the face grain of the panel

Table 1. *Statistical values of compressive strength parallel to the face grain of the panel*

Model	No. of test specimens	X_{min} [N/mm^2]	X_{max} [N/mm^2]	X_{mean} [N/mm^2]	$X_{mean}\pm f_{xmean}$ [N/mm^2]	$\sigma\pm f_\sigma$ [N/mm^2]	$V\pm f_v$ [%]	P_x [%]
I	5	41.42	48.12	45.39	45,39±1,35	3,03±0,96	6,67±2,11	2.98
II	5	56.56	59.52	58.08	58,08±0,49	1,11±0,35	1,90±0,60	0.85
III	5	46.83	52.25	48.77	48,77±0,99	2,21±0,70	4,53±1,43	2.03
IV	5	56.65	66.51	60.50	60,50±1,76	3,93±1,24	6,49±2,05	2.90

The analyze of the obtained research results of laboratory models showed that the mean values of compressive strength parallel to the face grain of models II and IV are higher for 19,09 to 33,29 % compared to the mean values of models I and III.

The mean value of compressive strength parallel to the face grain of model III compared to model I is higher for 7,45 %, as model IV has higher mean value compared to model II for 4,17 %.

The force-stroke diagrams during testing compressive strength parallel to the face grain of the panel are presented in Figure 4.

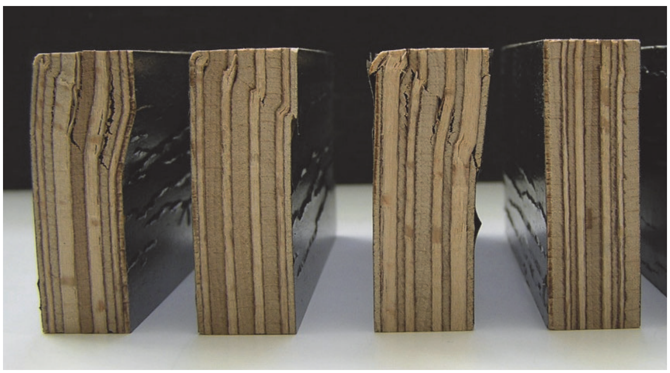

Figure 3. *Standard deformation of the test specimens after determination of compressive strength of plywood parallel to the face grain*

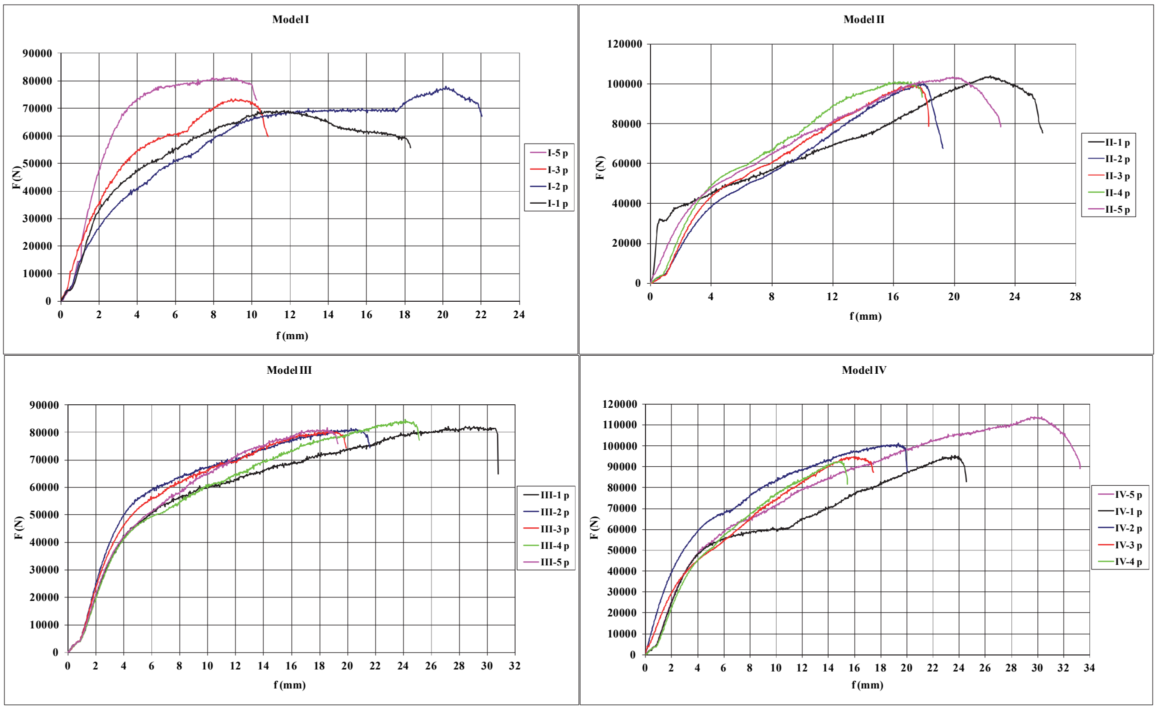

***Figure 4.** Force-stroke diagrams for models I, II, III and IV (parallel to the face grain)*

3.2 Results of testing the compressive strength perpendicular to the face grain of the panel

***Table 2.** Statistical values of compressive strength perpendicular to the face grain of the panel*

Model	No. of test specimens	X_{min} [N/mm^2]	X_{max} [N/mm^2]	X_{mean} [N/mm^2]	$X_{mean}\pm f_{xmean}$ [N/mm^2]	$\sigma\pm f_{\sigma}$ [N/mm^2]	$V\pm f_v$ [%]	P_x [%]
I	5	47.49	59.04	52.31	52,31±1,97	4,40±1,39	8,42±2,66	3.77
II	5	40.30	43.49	41.65	41,65±0,58	1,30±0,58	3,12±0,99	1.40
III	5	50.47	59.98	54.98	54,98±1,65	3,70±1,17	6,72±2,13	3.01
IV	5	39.88	45.99	43.67	43,67±1,03	2,30±0,73	5,27±1,67	2.36

The compressive strength perpendicular to the face grain of the panel in models I and III compared to models II and IV is higher for 19,78 to 32 %.

The differences between the mean values of models I and III are small as in the case of the values of models II and IV (Table 2). The mean value of the compressive strength perpendicular to the face grain of model III is higher for 5,1 % compared to the mean value of model I, as model IV has higher mean value for 2,52 % compared to model II.

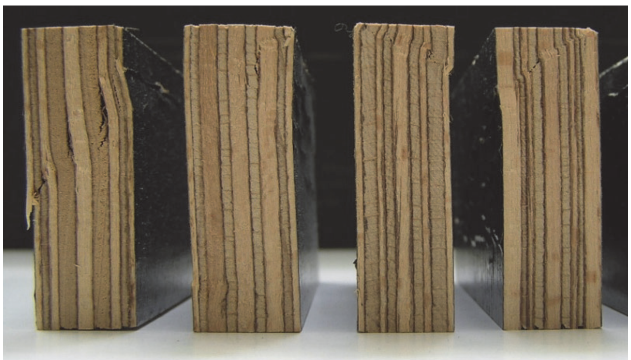

***Figure 5.** Standard deformation of the test specimens after determination of compressive strength of plywood perpendicular to the face grain*

The force-stroke diagrams during testing compressive strength perpendicular to the face grain of the panel are presented in Figure 6.

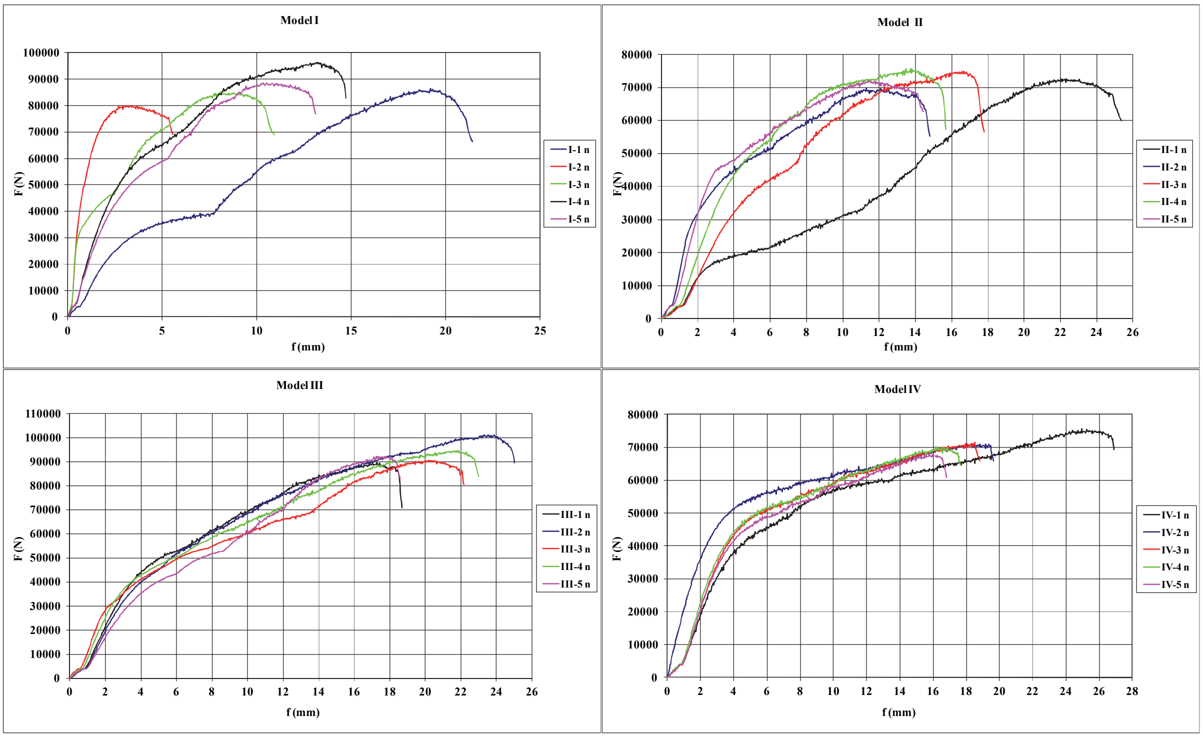

Figure 6. *Force-stroke diagrams for models I, II, III and IV (perpendicular to the face grain)*

4. DISCUSSION

The difference in the values of compressive strength between individual models is a result of the orientation of the veneers in the plywood structure against the action of compressive force, primarily of the veneers with thickness of 3,2 mm because they occupy the largest percentage of the thickness of the panel.

The compressive strength of wood is higher in the direction of the wood fibers compared to compressive strength in cross-direction of the wood fibers. By increasing the angle at which the compressive force loads the wood fibers the compressive strength decreases (Lukić-Simonović, 1983). Therefore, the compressive strength of plywood is higher in models that have a higher percentage of wood fibers that are oriented parallel to the action of the compressive force. For this reason, the compressive strength parallel to the face grain of models II and IV has higher value compared to models I and III. In fact, when testing the compressive strength parallel to the face grain of the panel, the wood fibers of two of the three veneer sheets with thickness of 3,2 mm are oriented perpendicular to the direction of the compressive force which contribute to lower values of this property in comparison with models II and IV, where the wood fibers of all veneers with thickness of 3,2 mm are oriented parallel to the direction of compressive force.

For the same reasons the compressive strength perpendicular to the face grain of models I and III is higher than in models II and IV. When testing the compressive strength in this direction, in models I and III the wood fibers of the veneer sheets with thickness of 3,2 mm are oriented parallel to the direction of compressive force. In models II and IV the wood fibers of all three veneers with thickness of 3,2 mm are oriented perpendicular to the direction of the compressive force which contribute to lower values of this property in comparison with models I and III.

Moving the veneers with thickness of 3,2 mm to the surface layers of the panel has small impact to the values of compressive strength, unlike the veneer orientation related to the direction of acting of compressive force, which has final impact on the values of this property.

The obtained values of compressive strength of tested models are within the values for this property listed in available literature. Dimeski and Iliev (1997) gives values of 64,16 N/mm^2 and 55,64 N/mm^2 for compressive strength of seven-layered and nine-layered beech plywood respectively. Iliev (2000) gives a value of 64,08 N/mm^2 for seven-layered and 49,11 N/mm^2 for nine-layered beech plywood.

All four models of plywood meet the requirements of the standard MKS D.C5.043 for structural plywood for use in construction, which prescribe a minimal value of 24 N/mm^2 for compressive strength parallel to the face grain of the panel and 12 N/mm^2 for compressive strength perpendicular to the face grain of the panel. The plywood models exceed the value of compressive strength parallel to the face grain of the panel for 1,9 to 2,5 times, while the value of compressive strength perpendicular to the face grain of the panel for 3,5 to 4,6 times.

5. CONCLUSIONS

On the base of the realized researches the following conclusions can be drawn:

- Related to the high values of compressive strength of plywood models, which exceed the defined values in the standard, it can be concluded that these panels are adequate for use in engineered structures in construction.
- Highest value of compressive strength is achieved in models in which the veneers with thickness of 3,2 mm are oriented parallel to the direction of the compressive force. Therefore, the recommendation for use of configuration of models II and IV in those cases when the panels are exposed to compressive stresses in the direction of the length of the panel (grain direction). By moving the longitudinally oriented veneers with thickness of 3,2 mm to the surface layers of the panel (model IV compared to model II) the compressive strength is increasing for about 4 %. Therefore, there is the recommendation for use of configuration of model IV in those cases when the panels are loaded to pressure in longitudinal direction.
- When the pressure is loaded a cross the length of the panel (cross grain direction), or when a greater equality of the values of this property in both directions of the panel is required, then the configurations of models I and III are recommended for use. Thereto, by moving the longitudinally oriented veneers with thickness of 3,2 mm to the surface layers of the panel (model III compared to model I) the compressive strength is increasing for about 5 %. Models I and III have almost identical differences in the values parallel and transverse to the panel's length.
- The production of plywood with different layout of veneer sheets in panel structure gives opportunities for production of panels that can meet the different requirements in their application. Using the same veneer sheets in panel structure but with their different layouts, panels with different strength characteristics required for installation in different constructions can be designed.
- The choice of particular plywood configuration will depend on the application area, i.e. the type of loads on which the panel is exposed during the exploitation period.

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INTERIOR APPLICATION OF MODIFIED WOOD

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ABSTRACT

In recent years, intensive efforts have been made in the development of methods to improve performance and durability, or mitigation and elimination of undesired natural defects of wood as a material. Modification of wood has become a common expression for different woodworking procedures and the use of various chemical agents that permanently affect the changes in wood properties. It, in a narrower sense, refers to the area of biological wood protection. Processing or modification of wood results in the achievement of some other positive characteristics as well such as: increased water tightness, resistance to acids or bases and UV-resistance, biological resistance, thermal resistance, or better mechanical properties. This paper describes a passive (by impregnation - physical) and active (enzymatic, chemical and thermal) modification.

Due to the improved properties, wood remains a competitive construction material, especially for wooden facades, fences, windows and doors, garden furniture, as well as for flooring and interior furniture.

Key words: modification, wood

1. INTRODUCTION

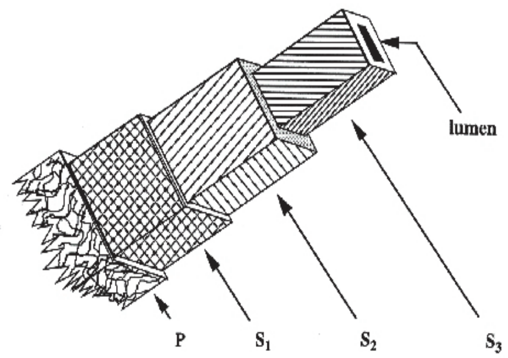
Wood is the tissue of the central part of the trunk and branches of trees, and is composed of cells whose main characteristic is that their cavity is surrounded by a rigid, dead wall. A living cell is composed of cell wall and protoplast. The cell dying leads to gradual disappearance of the living cell content, however excluding its walls and cell cavity. Wood cells have three basic functions: conductive, mechanical and storage function. Wood is a porous material. The cell wall is composed of two layers with central intercellular lamella: primary (thin) layer, outer (thin) secondary sub-layer - s_1, central (the thickest) secondary sub-layer – s_2, and inner (thin) secondary sub-layer – s_3 (Figure 1.).

Elementary wood composition consists of carbon (C), hydrogen (H) and oxygen (O), and absolute dry substance for various wood types shows minor differences in the elementary composition / carbon (C) = 49.5%, hydrogen (H) = 6.3%, and oxygen (O) = 44.2% /. The elementary wood composition includes nitrogen (N) as well, however, due to relatively low share, it is not included in the total elementary composition (it varies for 0:10 to 00:17% for different types of wood).

Concerning the chemical components of wood, it is necessary to make a difference between the major cell wall macromolecular substances such as cellulose, wood polyoses (hemicellulose) and lignin, which are present in all types of wood, and minor accessory material or extractive wood material (low molecular weight substances), such as the extractive and mineral substances, some organic substances soluble in water and inorganic substances, which are generally more associated with certain types of wood.

By its chemical composition, 97-99% of wood mass are lignin, cellulose and hemicellulose, which, depending on their share percentage, organization, and distribution in the tree itself, provide different wood types with different mechanical, physical, chemical and even aesthetic characteristics.[1]

Proper designing of engineering constructions requires the knowledge of particularly relevant wood characteristics, such as: physical (structure, density, size and shape, porosity and water content), chemical (composition, acidity, alkalinity), physical-chemical (sorption, volume changes, water movement), mechanical (elasticity, strength, hardness), thermal (expansion, heat conductivity coefficient, specific heat, heat diffusion coefficient), electrical (conductivity or resistance, dielectric constant) acoustic (conductivity, resonance, and absorption); aesthetics (colour, lustre, smell, delicacy, texture .....). As natural, renewable, economically justified, aesthetically specific and energy efficient material, wood offers great economic and technical advantages when compared to other materials (PVC, aluminium).



P: primary cell wall S2: central secondary cell wall
S1: outer wall S3: interior (tertiary) cell wall
***Figure 1.** Schematic Overview of the Wood Cell Wall Structure [2]*

Wood is the material of biogenic origin, therefore it is quite normal to possess both positive and negative features. As natural, renewable, economically justified, aesthetically specific and energy efficient material, wood offers great economic and technical advantages when compared to other materials (PVC, aluminium), as follows

- wood is a natural self-renewing material (synthetic lignocellulose cannot be manufactured), and as a living tree, it serves as carbon storage (in form of CO_2),
- it allows good quality processing with relatively low energy consumption,
- it is the only material to achieve required mechanical properties with relatively low density,
- it has good thermal, acoustic, and unique decorative properties,
- colour, in addition to texture, is one of the most important aesthetic wood properties (wood colours differ by types and intensity).

Considering the advantages above, wood has certain disadvantages as well:

- wood is susceptible to degradation if exposed to weathering,
- wood is susceptible to biological degradation (microbial activity, xylophagous fungi, insects and marine xylophagous pests)
- scissions (lengthwise crack in wood) as a negative wood property causing difficulties in construction,
- it is easily flammable material,
- it is weak heat and electricity conductor,
- it is hygroscopic and changes dimensions when changing the moisture content.

Adequate wood quality assessment requires, among others, the knowledge of its flaws. All deviations from average and normal appearance and normal wood properties are called wood flaws. Wood flaws can be classified into 6 groups:

- ✓ irregularity in roundwood shape,
- ✓ anatomy irregularity,
- ✓ irregularity in wood processing,
- ✓ damages caused by physical – mechanical impacts,
- ✓ colour changes and changes in colour and consistency,

✓ damages from insects.

The term flow appears quite differently, depending on whether we observe it from biological, technical or economic point of view. According to applicable regulations, new individual flaws, flaw terms and measurements are being introduced, such as: taper, curl, incorporated heart, cut heart, bark inflammation, etc. It contributes to the economic and commercial activity. Number of different types of flaws that occur in a living and a dead tree is enormous and a specialized study may treat it in that volume. However, normal exploring of wood as a material requires the knowledge of common flaws, occurring in trees of higher technical significance and strong economic and technical importance, and which serve as the basis for the classification of wood quality classes. [1]

Aforementioned shortcomings and flaws limit the use of wood compared to some other new materials. The studies of these defects and their removal or mitigation contribute to the appreciation of wood as a material.

2.THE CAUSES OF WOOD DECAY

During growth, processing and use, wood is exposed to numerous decay causes. It is subject to harmful effects of abiotic and biotic agents of destruction.

Structural wood, parquet, old furniture, as well as sculptures, picture or mirror frames, ethnographic collections and other various works of art made of wood are frequently attacked by wormhole-insects using wood as main sources of food, and even more as attractant.

Abiotic agents of destruction that simultaneously destroy wood are sudden changes in temperature, wind, UV rays of the solar spectrum and water in all three states. Constant changes in wood moisture (rapid wood drying and moistening) gradually comes to a change of micro-cracks, macro-cracks, twisting, warping, curvatures, bending, inaccuracy in processing measures and shapes, and other flaws. UV solar radiation primarily degrades lignin, wood polyoses to a lesser and cellulose to the least extent. [2]

The most common users of wood for feeding purposes are xylophagous insects and decaying fungi. Regardless of the group of organisms concerned, their attacks result in the damages that reduce the weight of wood suitable for processing into final products, as well as the quality of the product. During its exploitation, namely from the moment of cutting until the final product, wooden construction or structural components, wood is subject to the impact of different kinds of insects and fungi, depending on their adaptation to a particular type, zone or the level of wood moisture. The importance or detrimental effects of certain organisms depend on the level of product finalisation, or labour, energy and ancillary material embedded in it.

Biotic agents of wood destruction are anaerobic and aerobic bacteria, mould fungi, fungi discolorations, decay fungi, xylophagous insects and marine pests. Wood is first attacked by bacteria followed by mould. Certain types of mould in the later stages of development may cause discoloration. Colour change is the next occurrence observed in diseased wood and it is caused by the so-called blue stain fungi. In the last stage of rotting, wood is destroyed by "true fungi" from the subdivision *Basidiomycotina*. Certain bacteria infection significantly increases the permeability of the wood, while it slightly impairs its mechanical properties. Elimination of water from the wood - drying, provides the protection from fungi infection, however, the drying may sometimes lead to the increased attack of other insects (*Lyctidae*). Some insects (*Anobidae*) destroy wood attacked by xylophagous fungi in an easier and faster way. In seas, wood destroys often attach ship timber - shell (*Teredo navolis*) and (*Limnoria lignorum*) - shrimp. Each of these pests damage the tree in a specific way. They either penetrate deep into the wood (*Molusca*) or destroy it from the surface (*Crustaceae*). For these reasons, it is necessary to protect the wood against all biotic wood destruction factors.[3]

2.1 Natural Durability of Wood

Durability is a characteristic of the tree resist factors altering its natural characteristics for a shorter or longer period of time. It refers to the interval of a few months to a few thousand years, and significantly depends on the conditions of use. Natural durability of wood depends on the internal and external factors of wood resistance. Internal factors are anatomy and chemistry, while external factors include growth features, wood framing and stand. The longevity of wood depends on its chemical composition, resin, wood weight, cutting time (wood has higher durability if cut in winter because the moisture content in the wood is lower and low temperature prevents the development of fungus and insects), post-cutting process, environmental impacts and other. The species with a coloured black part are more durable than other species, since the resin and other components in it are toxic and thus prevent the development of fungi and insects.

The classification of wood by durability is as follows:

- ✓ High durability wood – central part of oak, larch, homemade chestnut, teak, mahogany, wenge
- ✓ Durable wood – pine, spruce, fir, ash, padauk
- ✓ Low durability wood – maple, beech, hornbeam, birch, alder wood, poplar, willow, cherry tree, horse chestnut.

Its persistence is mostly affected by microorganisms, insects, mechanical injuries and humidity. The highest durability is observed in wood used in dry premises, at low temperatures and without the presence of air. High durability is also observed in permanently submerged wood. The lowest durability is observed in wood used in the surface earth layer. Preserving increases the wood durability. [4]

3. METHODS FOR THE IMPROVEMENT OF CONSTRUCTION WOOD

Wood as material is used in construction, furniture and parquet industry. It is natural and environmentally friendly material that allows recycling, however, it has certain disadvantages as well. In order to ensure the durability of wood in the interior and exterior, we must protect it through appropriate processing system. Different modification processes, either natural (ebony), by chemicals and / or increased temperatures, enable the change of the chemical structure of wood grains resulting in the improved wood properties such as dimensional stability, durability, strength, adhesion of the coatings, waterproofing, wetting angle, etc. Traditional materials for protection and surface wood treatment have been replaced by alternative chemicals for environmental reasons. Furthermore, new nano coatings have appeared and when adding nano additives they can achieve improved surface properties such as hydrophobicity, UV resistance, self-cleaning, etc.

The use of modern methods, means and European norms and with the latest laboratory equipment has led to promising results primarily related to the effects of heat sterilization procedures and gamma rays, or modification of domestic species of wood, and in particular the determination of biological resistance of sterilized or modified pine. [5]

Modification of wood, whether thermal, physical, enzymatic or chemical, makes a big world trend today. Why is the modification of wood itself so popular nowadays?

Nowadays, we use different wood preservatives, in all forms, because wood is anisotropic and hydroscopic material. It is questionable to which extent are such treatment agents considered environmentally acceptable and what is their durability. Likewise, the substantial use of wood as raw material leading to gradual disappearance of good quality wood species, therefore the attempt are focused to the improvement of properties of less resistant and low quality species. Modified wood changes its internal structure and properties, striving to achieve the stability of its dimensions, to preserve the mechanical properties and resistance to naturally achieve biotic and abiotic factors. Modification of wood already proved in practice as successful alternative to protect the wood, giving more or less positive results as environmentally and economically acceptable, and as a solution to the lack of good quality and resistant species. Due to the improved properties, modified wood is used for carpentry, furniture production and in the construction of floors and decks. This paper suggests new methods of wood protection, and indicates wood modification as a promising method applicable in practice.

3.1 Thermal Modification

Heat-treated wood has been known for almost a century, but its use has not expanded in the industry due to relatively high cost of the procedure. As wood has appeared to be more and more valuable raw material recently, and various modification systems are sought to improve its performance and durability, this process has seen its new technology development and wide practical application. Various methods of thermal modification have been commercially applied in the past decade.

Wood heat treatment or overheating is a process which, without the introduction of additional chemicals but only under the influence of heat and pressure (and possibly humidity), modifies the chemical structure of wood cell walls. Changing the chemistry of cell walls we reduce its affinity to water, and improve its dimensional stability. Thermal modification is carried out at the temperatures of 120 ° to 280 ° C, in the presence of oxygen: at ambient or elevated pressure in the duration of 15 minutes to 24 hours, depending on the process type, type of wood, size, water content, and the target product properties such as required mechanical properties, and colour changing intensity. The length of the process defines the degree of wood modification.

The longer the process, the higher the dimensional stability and durability of the modified wood, however the density and mechanical properties are reduced. Prolonging the time of modification we change the wood colour, especially the colour brightness. The presence of oxygen during the heating process can result in significant cellulose damage, and subsequently in a noticeable reduction of mechanical wood properties. Therefore, the inert atmosphere (water vapour, carbon dioxide, nitrogen, vacuum) is most commonly used for overheating or the work pieces are overheated as submerged in industrial vegetable oil.

Colour changes during thermal modification depend on the temperature, the higher the temperature, the stronger the colours. In order to keep the desired aesthetic appearance of the surface of thermally modified wood, it is necessary to apply protective coatings since the thermally modified wood is subject to colour changes when exposed to the sun. Although the natural colour of wood is equalised in the thermal modification process, its tone is resistant to light and shall be stabilized.

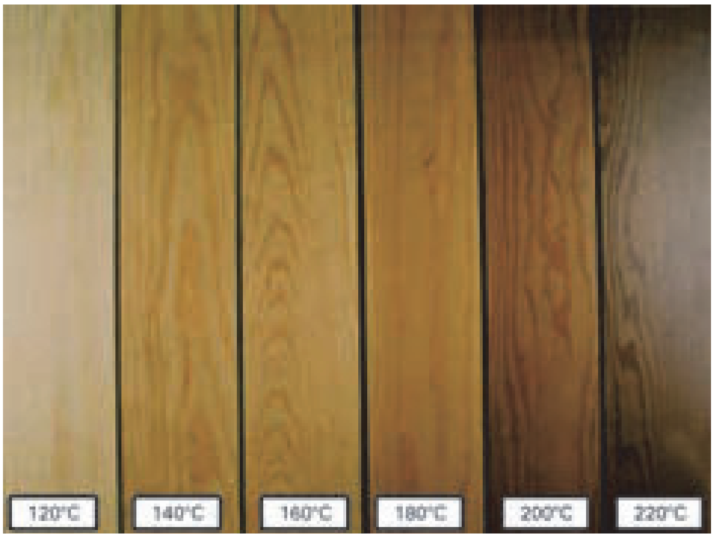


Figure 2. *Pine colours treated at the temperatures from 120 to 220°C (photo FTV Finland) [8]*

Drying methods at normal temperatures result in the already known stabilisation effect, however, heat treatments at much higher temperatures (up to 300 degrees Celsius) are proved to be more efficient. Positive effects include reduced wood work, reduced moisture resistance and increased biological resistance. The effect of high temperature leads to wood browning and an unpleasant odour which lasts for certain period of time, and the wood is not suitable for performance of all standard procedures of surface treatment and bonding. The lack of the cell wall middle layer resistance at high temperatures causes reduction of thermally treated wood hardness, but the most visible is the reduction of wear resistance. During the extreme heating, wood becomes more susceptible to cracking and occurrence of bumps.

Thereby conifers get the look of and old wood and are used to imitate rustic construction, while overheated broadleaf trees give the impression of an exotic wood. Applying this process, less valuable raw materials, such as inauthentic beech and ash core, can be converted to an aesthetic and technical value products (e.g. exclusive parquet) and overheated birch and poplar are used in Scandinavia for saunas and furniture. However, the overheated wood is most commonly used in outdoor structures for facades and fences, non-bearing structures, external floors, doors and windows, and wooden facade cladding.

High resistance to moisture and rot makes Thermo Wood extraordinary material for outside furniture and wooden structures in the gardens and terraces. However, it is not entirely appropriate for conditions which can lead to water supply or prolonged contact with moist soil. The exceptional thermal insulation and the absence of resins are also the properties making Thermo Wood ideal for hot and humid interiors such as saunas or swimming pools. When applied for flooring and furniture, exceptional dimensional stability and its beautiful colour come to a special focus. Namely, intensive heat treatment leads to a whole diapason of attractive brown shades and tones of Thermo Wood. In general, as shown in the Figure 1 above, higher treatment temperature leads to darker and richer (more intense) colours. [8]

The properties of the thermally modified wood depend on certain parameters, with the most important ones listed below:

- the type of heating medium,
- process duration,
- final temperature,
- wood moisture prior modification and
- wood species.

3.2 Enzymatic Wood Modification

In the production of wood composites of reintegrated wood we often encounter energy and environmental problems that arise due to drying or use of polluting binders. Enzymes act on the change of main wood components, primarily lignin, and already at room temperature, and thereby increase the activation of surface wood particles. A large number of reactive points provides interconnection and "bonding" of wood particles into a composite of satisfactory physical and mechanical properties.

The enzyme is specific (biological) catalyst, which can affect the speed of the chemical reaction. Enzymes function in a way that they lower the activation energy of a particular reaction and accelerate it thereby for up to several million times. The enzyme remains unchanged throughout the entire reaction duration, therefore, once a reaction comes to an end, it turns into another one completely unchanged. Enzymes affect neither the relative energy between the reagents and products, nor the respective reactions.

Enzymes are selective catalysts, which means that they react exclusively (specifically) with only one molecule type (group) ensuring high-precision chemical changes in wood. Enzymes catalyze reactions equally in both directions. Enzymes never change reactions in which they participate, but only the speed that leads to the establishment of equilibrium. [9]

Enzymatic modification of wood can be classified into two main groups:

1. Surface and
2. Deep (modification of solid wood)

1. Surface enzymatic modification is most commonly used for activation of the wood surface, especially solid wood to increase the wetting angle at surface treatment or at pasting and wood particles (chips) or activation of lignin mixed with wood chips to obtain non- adhesive wood plates.

2. In case of deep enzymatic modification, can not penetrate the cell wall itself due to the size of the enzyme, and the specific structure of wood cell wall - acting on the surface of wood fibres. For this reason, several methods (models) of deep enzymatic modification are applied, as follows:

a) Treatment (impregnation) of solid wood and wood particles using enzyme solutions (emulsions) for "softening of lignin in the intercellular central lamella to reduce the consumption of chemicals and energy for disintegration in the production of wood pulp, fibreboard and paper.

b) Targeted and controlled impact of xylophagous organisms on wood.

Enzymatic degradation of lignin is provided by white rot fungi of a bacteria. Since the degradation of lignin is the most complicated degradation requiring more time and special conditions, all subsequent procedures can be reduced to the levels of decomposition. Further application of hydrolytic enzymes results in the complete mechanical and chemical lignin degradation.[5]

3.3 Chemical Wood Modification

Many wood treatments are related to the use of various chemicals - it is a chemical modification of wood. Chemical modification of wood is a chemical reaction between the reactants of a chemical agent and the hydroxyl groups of wood. The best known and most researched ways to achieve a chemical bond between chemical agents and wood are etherification, esterification and acetylation.
For a successful modification, important parameters include temperature, time, catalyst and wood species. As pulp constitutes 40-50% of weight in absolutely dry wood, many chemicals and processes for the modification of wood derive from the field of breeding.

It is necessary to mention other forms of chemical modification of wood. The most important is the depth modification (modification of impregnation). The aim of the impregnation modification is to fill intermicellar spaces a chemical (chemicals) where the chemical associated to wood cell walls creates "confined space" to prevent swelling and shrinkage. During the impregnation stage it is important that the cell wall, at a certain point, increases or takes on a rounded shape to provide the molecular impregnator structure with the access to intermicellar space of the wood cell wall.

Impregnation modification procedure can be implemented in two ways: by diffusion or impregnation of monomers.

The presence of side and non-volatile substances in the wood cell wall affects the physical and biological characteristics of wood in different ways. The results of the deep modification of wood are dimensional stability of treated wood, reduced wood hydroscopy by blocking cell wall micropores and disabling the entry of water molecules and other substance molecules into the cell wall. It should be noted that perhaps after a while this barrier could still loosen and thus result in the dimension changes. Such deficiency shall be the basis for future research aimed at modification stabilisation and creation of unbounded molecular barriers.

Worth mentioning is also the resin modification. Alfred Stamm and his associates in Forest Products Laboratory, Madison (Stamm and Seborga 1941st) participated in the majority of previous resin impregnation activities. Based on his work, two basic protective products have been developed (impregnation and Compreg).

There is also furfuryl alcohol modification considered extremely suitable for wood modification as the furfuryl alcohol as a derivative is self-renewing. There were also attempts in research using malic acid and glycerol, and malic anhydride and polyglycerol.

Currently, the most researched means of chemical modification of wood is 1.3 dimethylol, 4.5 dihydroxy ethylene urea (DMDHEU). DMDHEU with the addition of a catalyst under high temperature in the reaction with OH groups of cellulose leads to etherification and the creation of a networked connection. Applying DMDHEU results in the release of formaldehyde from N-methylol compounds due to hydrolytic degradation and high temperatures during the modification process (Katović and Soljačić 1988a and 1988b). For this reason and due to environmental issues, it is tended to introduce new non-formaldehyde means. One group of non-formaldehyde means are polycarboxylic acids (PCA).[2]

DMDHEU is a suitable impregnating agent as the modified wood is resistant to the action of some decaying fungi, and the resistance of such modified wood is increased after a single rinse cycle. Modification of wood by DMDHEU-TV is still not efficient enough compared to the today's protective equipment. Some authors have shown that the release of formaldehyde can cause great difficulties due to the toxicity and carcinogenicity threats of formaldehyde, and its allergic dramatic effects have been evidenced (Soljačić, 1992; Katović, 1998). It can be assumed that the problem of free formaldehyde is not only environmental but also an economic issue. Important role in the selection of non- formaldehyde has an economic factor.

Citric acid (CA) is widespread in nature and fully meets the economic and ecological requirements. The first experiments of wood modification using citric acid provide multiple increase of biological resistance to some decaying fungi. Results show that the modification of citric acid is a promising alternative method to protect the wood, but further research is needed to optimize the concentration of CA (citric acid) and SHP catalyst in water solution, the time and temperature of thermal condensation to improve the desired wood properties.[6]

3.4. Physical Wood Modification

Physical modification is impregnation of wood using solutions or emulsions of different monomers polymerized in the wood but not chemically bound to it.

- impregnation using Impreg and Compreg means (Seborg, 1941),
- impregnation with 2-hydroxymethyl-methacrylate (HEMA) and methyl-methacrylate monomer (MMA)

In recent years, impregnation of wooden art for restoration purposes is provided using solutions or emulsions of polyethylene glycol of different concentrations, impregnation with Malic acid, and glycerol and malic anhydride and polyglycerol, and impregnation with tetrachloro-silane ($SiCl_4$) and various silicon derivatives.

In all above mentioned wood processing procedures it is difficult to avoid the use of load pressure, either due to a faster and more effective penetration of various means in the porous capillary structure of wood, or due to the reintegration of wooden parts in composites. Therefore, it is rather difficult to find a strict boundary between individual treatment processes and the so-called compression or pressed wood, which could be classified in the group of physically modified wood.

4. CONCLUSION

The tendency to improve the properties of wood as an engineering material, to reduce its anisotropy and other undesirable characteristics and, in this regard, to develop new products based on wood and various polymers has existed for years.

To ensure the durability of wood in interior and exterior, we must protect it by a suitable processing system. Different modification processes, natural (ebony), chemical and / or by increased temperatures, it is possible to change the chemical structure of the grain of wood and wood improve properties such as dimensional stability, durability, strength, adhesion of the coating, water repellency, wetting angle, etc. Traditional materials for protection and surface treatment of wood, were replaced by alternative chemicals for environmental reasons. The careful choice of method modification allows targeted analysis of specific problems, and their good combination provides arguably the identification and detection of observed phenomena.

In order to ensure the durability of wood in the interior and exterior, we must protect it through appropriate processing system. Different modification processes, either natural (ebony), by chemicals and / or increased temperatures, enable the change of the chemical structure of wood grains resulting in the improved wood properties such as dimensional stability, durability, strength, adhesion of the coatings, waterproofing, wetting angle, etc. Traditional materials for protection and surface wood treatment have been replaced by alternative chemicals for environmental reasons. Careful choice of modification methods allows targeted analysis of a specific problem, and their good combination provides unambiguous identification and detection of observed phenomena.

The task and the interest of all engaged in wood processing is to definitely understand the nature of the material they are working with, not only as raw material with all its features, but also as a substance of organic origin presenting food for a large number of insects and fungi. Until now, a series of preventive and repressive measures for wood protection has been developed at different stages of processing and use of wood, and not only physical and chemical, but organizationally-technical as well. Proper manipulation with such, in many ways specific, material provides its saving, rational consumption, better quality products and higher profits which is the ultimate goal of every production and successful business.

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TYPOLOGICAL ANALYSIS OF MACEDONIAN TRADITIONAL HOUSE IN STRUSHKI DRIMKOL - VEVCANI REGION S INCE LATE 19-TH AND EARLY 20-TH CENTURY

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ABSTRACT

A thematic examination has been made about typological analysis of tradicional macedonian architecture, in order to endorse the architectural categories raised in all national constructive creations on macedonian ground.

Although the examination has been inserted on one region in southwestern part if Macedonia, there were separated the main features of national architectute wich are distinctive for this surrounding. The values who differences this region from the others were detaily analyzed.

There were inclided more methods in the examination. These methods assisted to formulate all parameters used by national constructor.

The inserted examination results with the establishment that national architecture abounds with aesthetical values. These values insight from every detail, and the national constructor with enormous constructive skill succeded to presen them in real light.

Key words*:* Vevcani, tradicional macedonian architectute, constructive skill, national constructor

1. INTRODUCTION

This paper represents a symbiosis of some aspects form which the old Macedonian architecture, i.e. folk architecture is analyzed. The old architecture of the village Vevchani is the basic point of the entire research. This architecture style covers the period of the XIX and XX centuries, which is the era when the social and economic conditions created conditions for development in the domain of the profane, architectural design, which in this period reaches its highest qualitative peak.

What is common for rural compositions on the entire territory of Macedonia is that the latter differentiated themselves as a result of attempts to adapt to regional geographic and climatic factors. This is particularly notable in those villages, which are wrapped over the mountain ridges. In those villages, the houses are perfectly adapted to the terrain, location, all for the purpose of maximizing the benefits of the nature. In fact, the choice of location for the building has been influenced by several different factors: the natural and social conditions, availability of natural resources, safety factors, etc.

Formation of rural settlements is continuous process that takes a long time. This process starts spontaneously, becomes gradually intensified, reaching its climax as a result of tradition and the possibilities for existence, and then begins stagnation and gradual extinction. This is the case with almost all the villages, which are increasingly being abandoned and lose their population as a result of socio-economic opportunities.

Few villages have succeeded, despite all, to preserve their typical cultural and historical heritage, and thus to preserve the authentic expression, and with that, the spirit of a time that long ago vanished. Between all of them, Vevcani undoubtedly soars. Today, Vevcani is an ideal combination of age-old beauty woven with a new time, yet without any distractions to the beauty of tradition, and nature.

Vevcani, captivating by its individual specifics in the positioning of the houses, belongs to the group of Tsintsarski type of rural settlement (transition from rural to city type - Balkan type), and is a village of compressed configuration. The original building culture of this village allows each building to represent an unbreakable thread of the surrounding environment, the surroundings, in a way in which the the buildings themselves gain a specific spirit, which differentiates this village from the rest.

2. PURPOSE OF THE RESEARCH

This paper is a part of larger research for valorization of the national heritage in terms for rural development, precisely, for development of the rural tourism. The main goal of this research is the need to better understand those architectural works that best represent the builders' spirit of the folk masters of our region, their sense for practical problem-solving and the need for continuous improvement in spatial organization and the possibilities to incorporate traditional house in modern tourism. In other words, the work is a result of the need to define the identity of the Macedonian house.

The objectives focus on typological analysis of the buildings that are the subject of this research, particularly the houses in Vevcani, Macedonia, built in the late 19th and early 20th century.

3. RESEARCH METHODS

The survey was conducted using several well-known methods, which enable to exercise the right approach to obtaining the information needed. These methods are:

Method of direct measurement

The method of direct measurement relies on measuring the dimensions of certain parts of and the whole building, for the purpose of more accurate analysis of typological variants that appeared in the architecture of the houses in this region.

Parallel method

Analysis of selected examples - houses:

- Examined, described and explained the most important architectural concepts
- Identified the types of objects in the same rural setting

Historical method

The historical method in this research was necessary for the purpose of coming to proper and correct understanding of the impact of typological concepts in the architecture of the houses in Vevcani, as well as concepts of the same organization of houses in the late 19th and early 20th century.

Comparative method

Analytical and graphical tests were applied, especially in the research of the buildings' typology and its impact on the organization of the house in general.

4. TYPOLOGICAL ANALYSIS OF THE VEVCANI HOUSE

The originally constructed buildings in this region were formed as *huts* or *baskets* with wooden construction and covered with straw. Today one can find remnants of these former habitats.

Next form that occurred was the so called basement or *ground-attached* house. Built of poor material, with cattle stays and a separate area – *the house*, that always had a fireplace and was separated with hardwood or wicker wall. Walls are made with small openings with two-door shutters.

The gradual development of the house and its modification occurs as a result of the change in the lifestyle of the residents, as a result of their changing habits. Thus, over time due to the increase in the number of family members in addition to the central premise (*the house*), a small room called "chamber" was added. On the other hand, due to well-developed tradition of mutual respect and foster good family relationships to these premises was annexed a drawing or entertainment room. These were built from lightweight material with net-like construction, a filled wall mask made of thin branches, and coated with a mixture of clay and straw, with a wall thickness of 10 to 30 cm.

Later on, a need arose of an auxiliary warehouses curse, which kept foodstuffs and stored products are not used in everyday use. An ante-room or a porch that provided access to the different areas in the house then became part of the entry area.

In one-level buildings massive stone walls are applied, serving as basic structure for annexing additional rooms in horizontal or vertical direction, built of light-weight materials in net-like construction with filled wall mask made of thin branches and coated with mud.

Later, in the late nineteenth and early twentieth century, the house develops in vertical direction and two-story and three-story houses emerge, as a result of the need for more space. Accordingly, the stone walls rise from the ground to the upper floors, their thickness narrowing vertically in line with the reduced bearing capacity (from 80 cm on ground floor drops to 70 and 60 cm on the upper floors). This building style results in the creation of the first floor open - multifunctional space – the balcony or the loggia.

A distinctive form of loggia typical for the Vevchanska house is the narrowed form loggia – teliz, and which was attached to one side of the building. Thereby loggia- telizot front was closed with vertical planks - pardias, from the bottom to the top of the floor height. Loggia - telizot had small openings with arch-like finishendings of the top that allowed for air circulation and contribute to the enrichment of the facade.

Porch and loggia- telizot were attached on any side of the building, as well as centrally or around the entire building perimeter. In most cases, they were placed centrally, thus preserving the symmetry of the building.

In later stages of development a toilette (so called *ale)* is added as a mandatory element either as attached to the rear side of the building or as a separate construction element of the house.

A very particular farm house construction model that occurs later on was the so called fraternal households' house. It is a model of most complex habitat, and occurs as a result of the need for intimacy of the extended family. In later periods significant impact is made by the rise of modern architectural movement or transfer and application of constructive - aesthetic details from the master group that absorbed all their experience from working abroad, where he had the opportunity to meet with different and contemporary structural systems. It is these influences that are most evident in Vevcani, the village being the place where these masters' groups actually originated from.

4.1 Typological Analysis of Multi-Storey Variety

Typological variety of architectural objects is dependent on the position of the same, and the horizontal and vertical development of the building's overall basis perimeter.

Vevchanskata house is located in a mountainous area and a steep terrain, so that the back wall always relies against the soil and enters the terrain, while the top floor is made of stone or net-line construction of inter-woven thin branches, most often hosting the family and the guest rooms.

Accordingly, one can conclude that Vevchanska house is a multi-storey house. Once can hardly find a ground or a one level house. The buildings are form of towers, and this conception is the result of the need for the purpose of defense and isolation from external enemies, but also conditioned by the need for the maximum possible space.

Old Vevcani houses can be classified into three groups, as follows: single-storey houses; two-story houses and multi-storey houses – towers.

Single-storye houses in Vevchani are a rarity. Much larger is the number of two-storey houses, implying that the act of building a house was very important to the village's masters. Single-storey houses have ground floor of massive stone construction. This part of the house hosts the economic, i.e. work units or premises where cattle were housed, and food- storage compartments. This part of the house also included vertical communication elements – stairs, which connected the ground floor to upper levels. Departments for housing cattle (so called "kerala") were divided into: oxes keeping sections, horses and donkeys keeping sections (so called "ar") whereas the section in which house furniture was stored was known as the "klet". Basement units are entered directly from the courtyard. This section has no windows, and if there are any they are quite small. Right above them, i.e. on the first floor the rooms where people lived we situated. At first, right on top of the ground-floor furniture storage are, was the fireplace and this living area was called "*the house"*.

Later on, in line with the increasing needs of the families, this room gets vertical compartments forming different chambers.

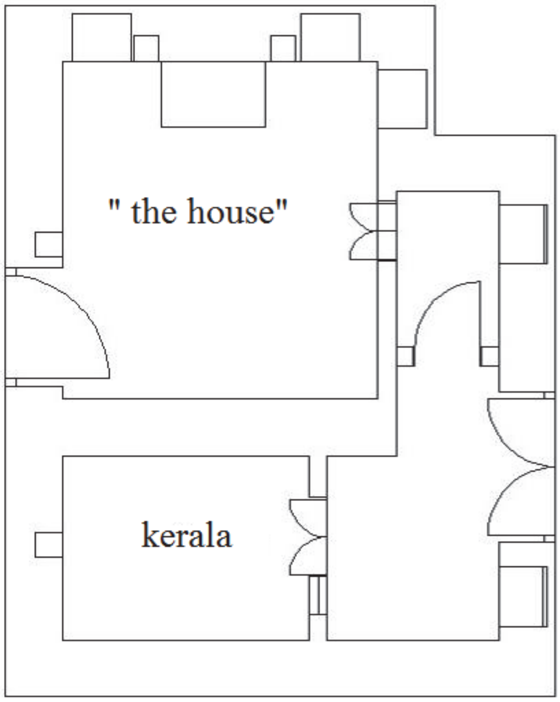

Figure 1. *Single-storey house of the nineteenth century with the included room house, with cattle-keeping and annex - chamber*

Consequently, a classification of the different rooms in the household can be made. So, a the ground floor housed the economic and commercial premises, then the upper floor housed the family rooms and the house, as well as representative offices guest room and balcony.

Most represented and contemporary model of a Vevchani house is the two-storey house. There are a number of similarities with the single-storey house. The latter also have a furniture storage ground-floow area, and the main difference of this type of habitat is that it has a significantly larger number of rooms on the upper levels.

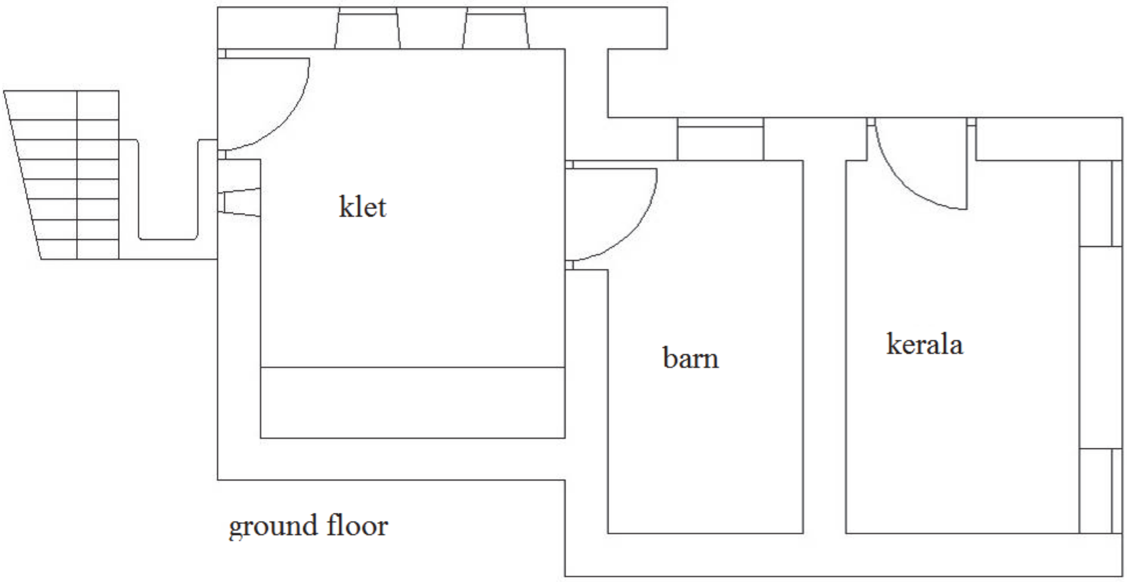

Figure 2. *Ground floor of two-story house at the end of the nineteenth and early twentieth century, with additional rooms in the ground floor th (barn curse)*

On the first floor are located the house and other family pro-stories, while second - the floor houses the guest rooms and balcony.

The terrace is the largest part of the house and is used for welcoming guests hosting various celebrations.

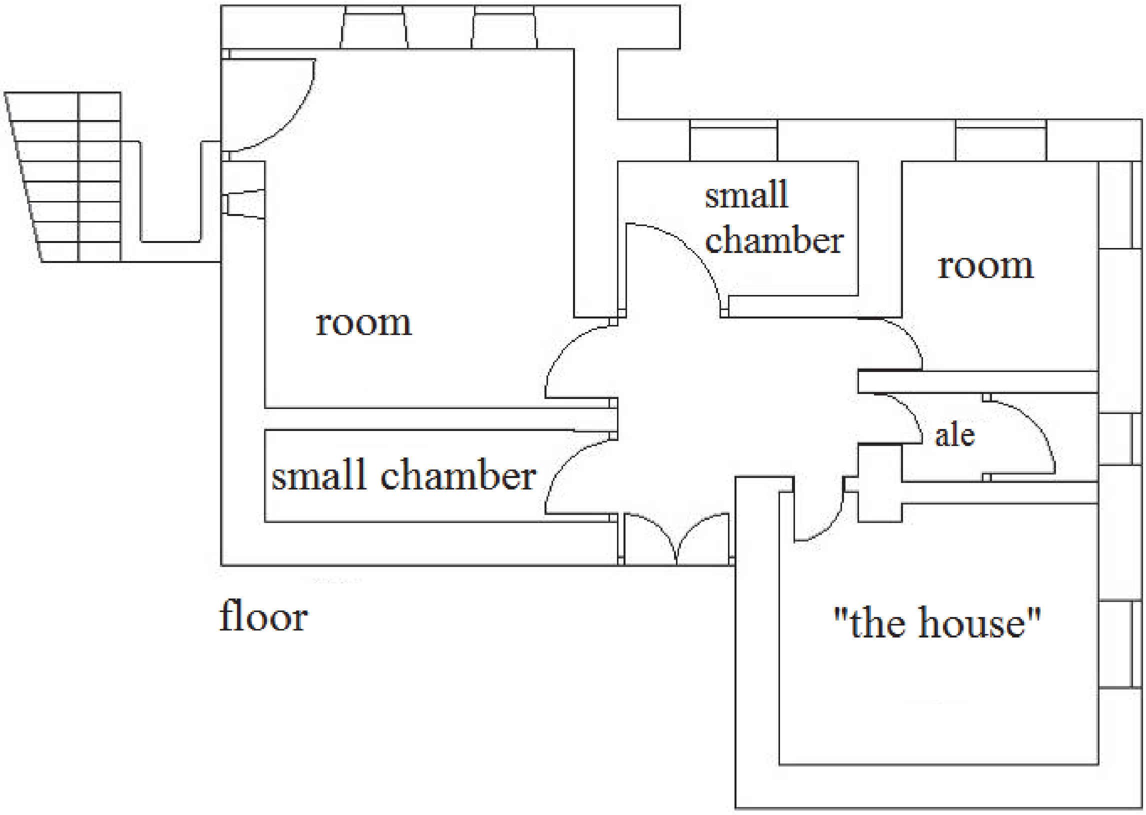

Figure 3. *Floor and residential areas of the two-story house, at the end of the nineteenth and early twentieth century (house, room and small-chamber)*

Feature Vevcani-formal multi-storey houses that have a variety of accessories on the outside form a continuation in the direction of free space - teliz. They have a length of about one and a half to two meters. Typical teliz extends half of the wall or the entire wall.

The so –called "tower" house represents a type of house inherent to Vevcani. It is a house with more than two floors. Because Vevcani is a settlement of dense type, and thus did not allow for real opportunities for horizontal expansion of the house facilities, the houses expanded vertically instead. In fact the tower is a palace type of house - a palace which expressed the entire splendor of its owners. The vertical expansion of the houses was partially done for security reasons.

Quite different was the case with the specifics of the so called fraternal house hold house. Fraternals lived under the same roof, but each within their own living quarters sharing a common wall. From the point of view of functional organization of this not much is different from the rest. The ground-floor rooms are economic units (porch, furniture storage, and barn), the first floor is where the living quarters (house rooms) are housed, whereas the second floor is the level of charming balcony rooms. The main marking features of this type of house are the two separate entry doors to each of the fraternals 'parts of the house. The fraternal house can be organized in two ways. First, the house is differentiated in two spatial units. Each of them has its own house, room and upstairs balcony set, furniture storage and porch set on the ground floor. In the second type every family has a house and room but at different levels.

The terrace is the only common room.

5. CONCLUSIONS OF THE TYPOLOGICAL ANALYSIS

The analysis allows us to conclude that due to the diversity of architectural-constructional approaches which resulted in numerous different house designs, one can hardly set aside one characteristic house design typical for the Vevchani village. All types of basic concepts resulted in original solutions, which distinguished the creative potential of the masters. Vevcani abounds with buildings the constructive elements' aesthetic treatment of which is not repetitive, allowing us to only to determine the basic division in terms of their concepts.

Based on the basic characteristics and structural elements Vevcani old house can be classified according to the following criteria:

1. According to the manner of organization of ground parties in the old Vevcani house:
- House with standard manner organized ground floor that houses the chambers and economic classes;
- House with ground floor that houses only economic units;
- House with ground floor that housed economic classes with some craft or manufacturing facilities (grocery, butcher shop, tailors).

Ground-floor level in Vevchanska house usually accommodates economic and commercial departments. Also, the furniture storage area is a must on this level, as an indispensable part of every single house. Economic departments are rooms for cattle (Kerala), food storage area and the like. This part of the house is where the stairs leading to the upper floors are located also.

2. According to whether the house contains a loggia, the buildings can be constructged in several variants:
- Type of house without a porch;
- Type of house with a balcony, so called "Chardaklija house";.
- Type house with aq narrow, two-side-closed balcony, so-called "teliz;
- Type of house with a loggia and a teliz;

Vevchanskata house is a Chardaklija house. The balcony, i.e. chardak, can have diverse structure and a variety of sizes and shapes, but it is still mandatory element of the house. In fact it is the area of the house towards which all other rooms of the house gravitate.

3. According to the position of the balcony, the objects can be:
- Type of house with centrally positioned loggia;
- Type of house with corner-side positioned loggia which covers most of the facade;
- Type of house with a porch that covers the entire main facade of the building.

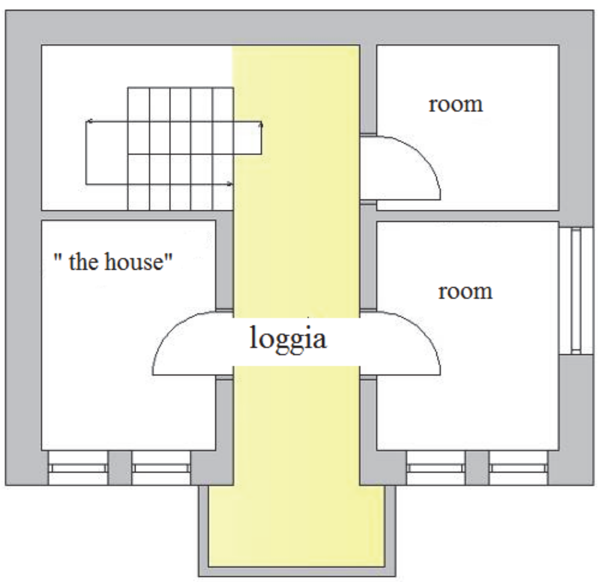

Figure 4. *House with centrally positioned loggia*

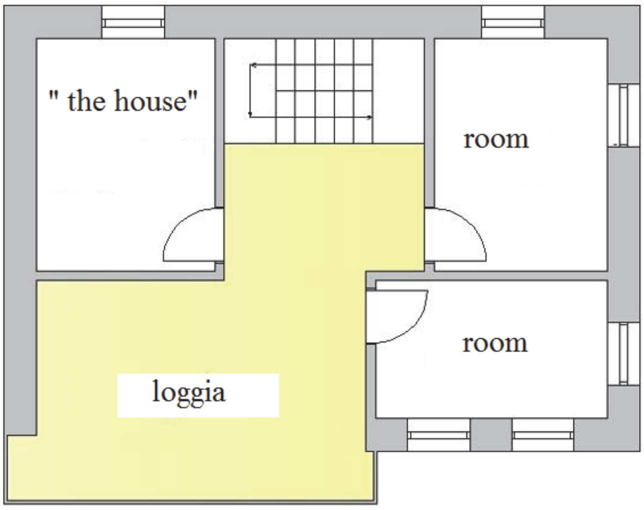

Figure 5. *House with corner-side positioned loggia*

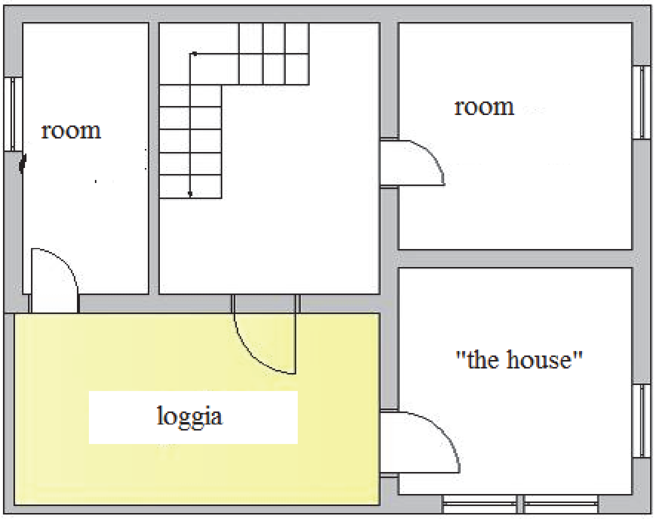

Figure 6. *House with corner - frontally placed loggia*

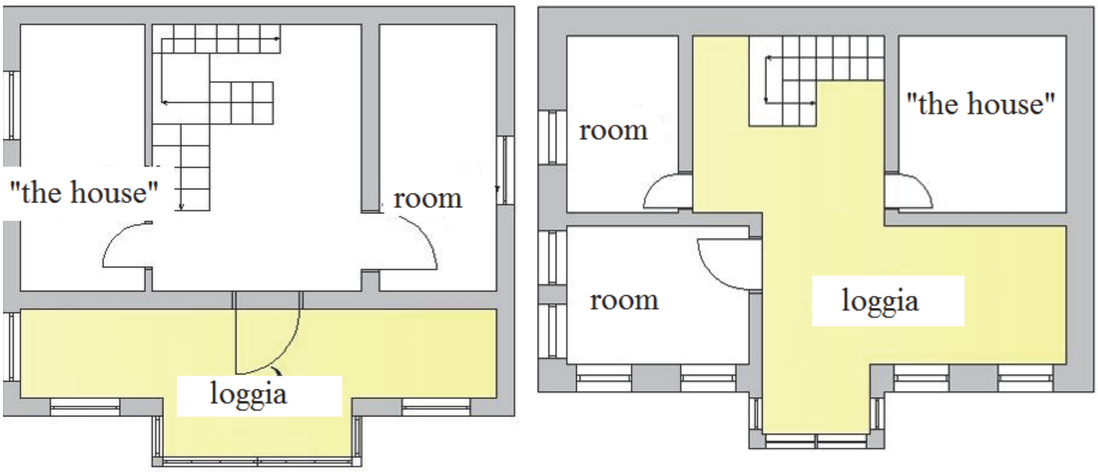

Figure 7 and 7a. *Positioning of the balcony in relation to the main facade:*
Frontally set loggia which runs to the interior of the building.

4. According to the type of porch, the houses can be classified as:
- Type of house without a porch;
- Type of house with open loggia and
- Type of house with covered loggia.

5. According to the form of the porch, houses can be classified as:
- House with frontally positioned loggia;
- House with a loggia that extends to the interior area;
- House with narrow-type loggia - teliz;
- House with a loggia that transforms into a teliz attached to the main facade.

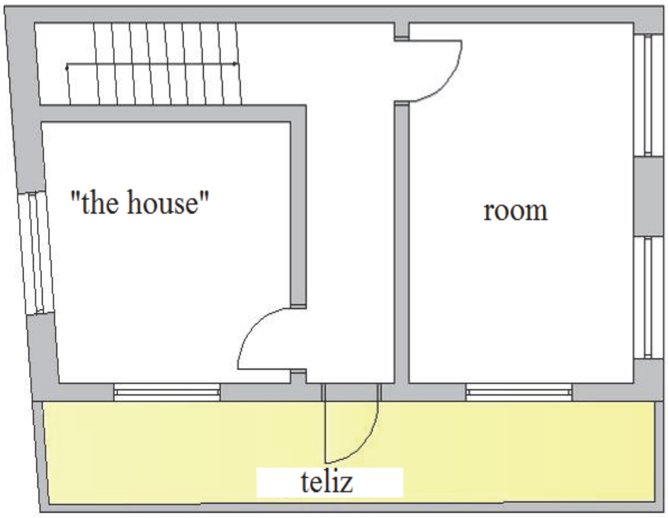

Figure 8. *House frontal charming loggia, which narrows and becomes teliz.*

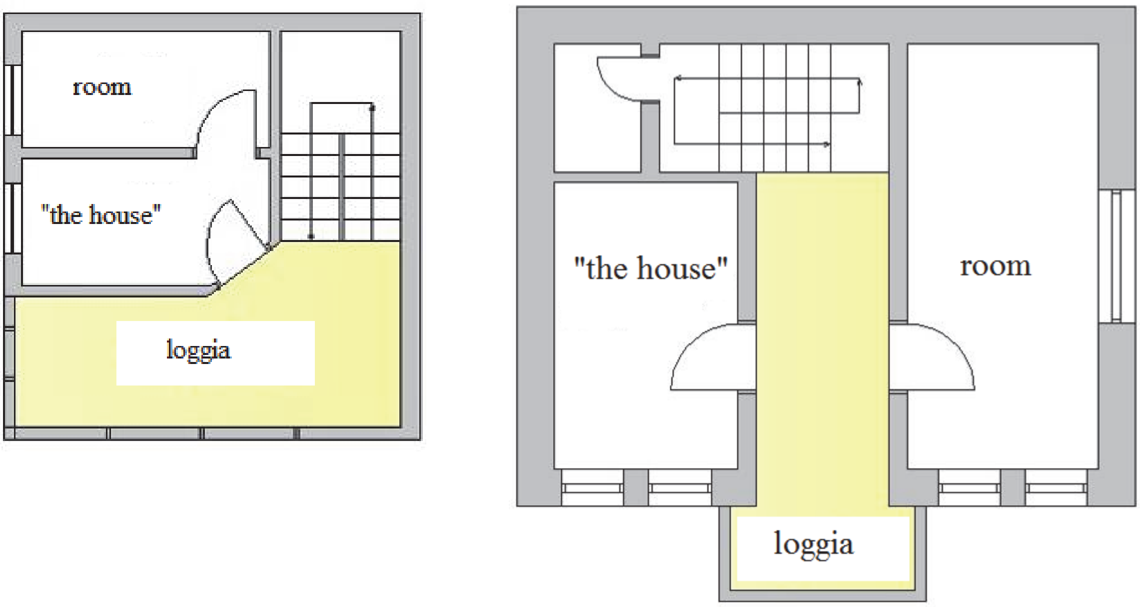

Figure 9 and 9a*. Forms loggia: in line fa-and drawers overhang charming loggia*

6. Based on the balcony positioning in relation to the basic spatial volume of the house, the houses appear in two variants:
- House with console-drawn loggia attached to the main facade;
- House with a loggia incorporated within the house's basic dimensions perimeter.

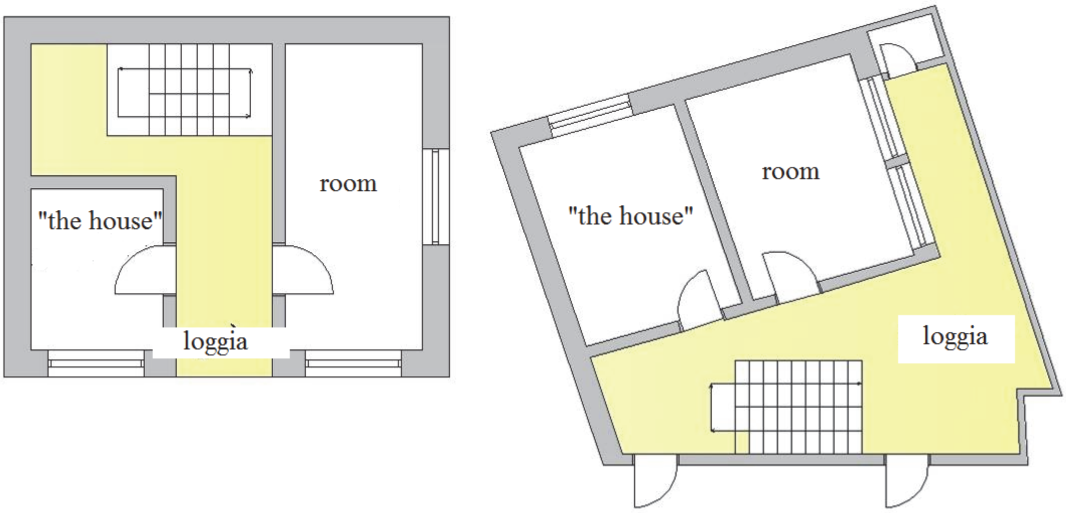

Figure 10 and 10a. *Positioning of the loggia in relation to the spatial volume (inside the building and out to the exterior)*

In most cases the loggia is positioned as a console-drawn element attached to the main façade, thereof acquiring its special significance. The other variant is a semi-closed-type or an open-type loggia positioned frontally along the entire façade length.

7. According to whether the object was erected as an independent structure or shares a common wall with another object, there are:

Independent houses; Common-wall houses; Fraternal houses.

In Vevchani most of buildings share common walls and are aligned in sequences due to the village dense-type lay-out. Independently standing houses – towers can be seen sporadically, while the so called fraternal houses are more of a rarity. Development of the rural tourism and quality of rural environment , implements a lot of factors, btw, tradition, orientation, topography, climate, water, insulation, roads, recreation, food, etc. Valorization of those significant factors can simplify the way to “give air” to the villages, and make them live properly.





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EXAMINATION OF SOME STRENGTHS FIXED ANGULAR COMPOSITION IN THE CONSTRUCTION OF ELEMENTS OF DISHES MADE OF REFINED PLATE WOOD CHIPS

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ABSTRACT

In this paper we study comprised of some strengths that are most characteristic and always occur in exploration corps elements of a kitchen, standing in as (low) corps elements and the hanging elements or other components in the kitchen. Studied are fixed connections with soldering elements made of plates of chips and accessories with elements of sticking and wood rounded corks and other mating elements are usually applied in practice in the construction of elements in corpus product.

Investigation for strength of bending are derived according to recognized methods Kjuchukov (LTU-Sofia) and International Standards BDS 9165/7, BDS 16712/87, BDS-13087/89. According to the methods and standards, conducted tests on test bodies made of plates of chips and application of structural connections, just sticking with the elements and the adhesive and rounded corks and other making constructive element of a kitchen furniture.

The selected material (refined plates of wood chips) is under BDS312-3.The tests for these features strenght fixed angular structural compositions obtained are comparable with results of tests group Authors from other countries on the same issue in some equivalence.

Key words: strength, bending, test body element, plate, chips, hull, gluing, wood rounded corks, force, breaking deformation

1. PREVIOUS RESEARCH

By studying the literature, we found that our conditions of scientific work in the field of strength of structures of furniture is best to choose the classical way of determining the strength of bending of some constructive relationships through experimental means of testing the strength of bending for structural angle connections according to the method of Kjuchukov, Albin Ekelma. Kjuchukov are presented and compose the BDS - Bulgarian state standards for wood construction, are N (BDS:14, 15, 18, 23, 24, 25, 26, 27, 30, 32, 35, 39, 41, 42, 43, 44, 82 , 90);

The literature that was available to us we can bring forward some considerations that are important to mention here, and that is that we met with several recognized methods for constructive and strength of bending for properties of the angle constriction compositions in kitchen furniture.

For experimental testing the test body, we are using special equipment and universal machinery for small test body who are represent the angle fixed connection of the kitchen furniture.

Scientists for determination of strengths of bending continues to the field of scientific research to find new methods to study for the strength of structural compositions with experimental investigation.

2. PURPOSE AND METHOD OF EXAMINATION

The main objective of this paper presents the determination of the strength of the bending, constructive connections who are used in constructions of kitchen furniture made of wood panels from wood particle . Frequently used structural compositions who are fixed and montage- de montage links. Making constructive elements in fixed angular compositions (test fixture) we decided on the following constructions: only with sticking (with glue) and with glue (sticking) and rounded wood wall-rivets, for montage in constructive fixed composition.

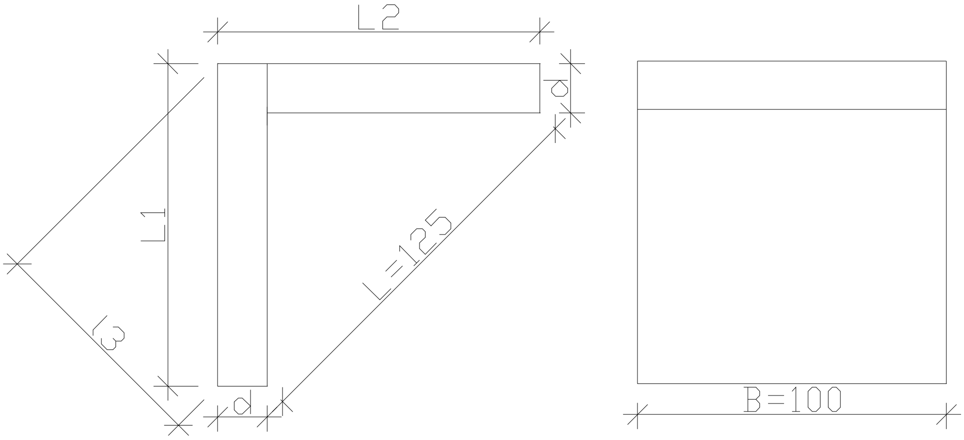


Figure 1. *Dimensions of test fixtures*

L - distance between the inner edges of the test body; L1 - length of the longer element of the test body; L2 - length of the test body; B - width of the test body; l3 - a distance that determines the length of the outer edge of the line that passes through outer edges of the test body; d - thickness of the elements of the test body

As a basic material for making angular compositions selected made of wood panels from wood particle manufacturer Kronospan.

These plates Kronospan to European Norms EN 312 and Class E1 and BDS 5508th.

The choice of the conjunction it is rounded wood wall-rivets for connection of the element in test body it is under methods of Kjuchukov and are shown in Figure 2.

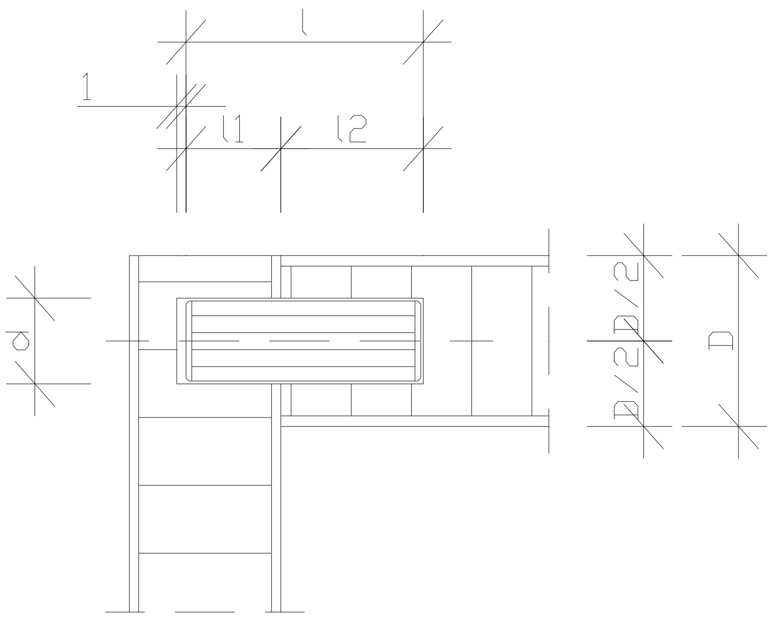
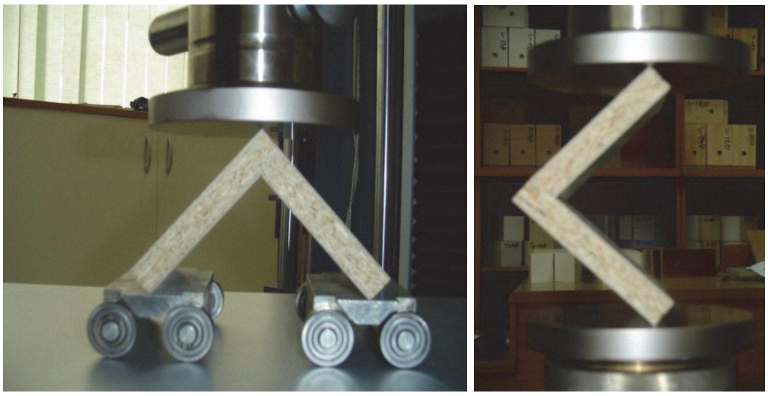


Figure 2

The elements of the test fixture with a thickness of 16 mm, and according to them rounded wood wall-rivets are selected with the following dimensions: thickness d = 8mm, and the length of wood wall-rivets is l = 25mm. As the conjunction tool, used is Single component waterproof adhesive Chromos Drvofix VO tip-3, made on the basis of polivinilacetat water dispersion. Purpose of putting materials that are exposed to sun or humidity short-acting water or circuit which requires about D3.

Characteristics of glue: PH value: 2,0-3,0 (DIN 53 785) Viscosity: 14000 ± 4000 m Pas (RVT ISO 2555, B6/20/23 ° C); Contents of dry matter: 54 ± 1 (DIN 53,189) Density: 1035-1045 kg/m3; optimum operating temperature: 20 ± 5 ° C.

In Figure 3, shows how the experimental investigation of test bodies in the universal testing machine. Test body is burdened with the forces of bending and it is examined with opening and closing elements of test body.



a.Investignation by opening the elements b. Test closure elements

Figure 3. *Test method for test bodies (method of Kjuchukov)*

3. DISCUSSION

Bending strength expressed through the middle point of bending the corner fixed only by sticking for together the elements from test body, with opening of the elements it is 464 Nm (see Table 1).

Table 1

N^o	*Corner connection*	Msr Nm	S Nm	Fx	fs	V %	fv %	Sr Nm	p %	n br.
1	2	3	4	5	6	7	8	9	10	11
1	only by sticking and opening the elements	464	43.25	0.093	1.441	9.31	0.310	2.883	0.0062	15

Deformation of the test body with a fixed angle compositions only with sticking of elements made from panels of wood particle with the opening of the elements are complicating with deforming in panel, but not in sticking the elements.

Bending strength expressed through the middle point of bending the corner fixed only by sticking for together the elements from test body, with closing of the elements it is 161 Nm (see Table 2).

Table 2

N^o	*Corner connection*	Msr Nm	S	V %	Sr	p %	n br.
1	2	3	4	5	6	7	8
1	only by sticking and closing the elements	161	35,3	0,198	1,25	1,54	15

Bending strength expressed through the middle point of bending the corner fixed with sticking and rounded wood wall-rivets for connection of elements from test body, with opening of the elements it is 367,6 Nm (see Table 3).

Table 3

Nº	*Corner connection*	Msr N.m	S Nm	Fx	fs	V %	fv %	Sr Nm	p %	n br.
1	2	3	4	5	6	7	8	9	10	11
1	*with sticking and rounded* wood wall-rivets*, and opening the elements from test body*	367.6	68.7	0.186	2.29	18.7	0.62	4.58	1.2	15

Deformation of the test body with a fixed angle compositions with sticking and rounded wood wall-rivets for connection of elements made from panels of wood particle with the opening of the elements are also complicate, and deformation it is in the pane (in the boards) with banding.

Bending strength expressed through the middle point of bending the corner fixed with sticking and rounded wood wall-rivets for connection of elements from test body, with closing of the elements it is 150 Nm. (see table 4)

Table 4

Nº	*Corner connection*	Msr N.m	S Nm	Fx	fs	V %	fv %	Sr Nm	p %	n br.
1	2	3	4	5	6	7	8	9	10	11
1	*with sticking and* rounded wood wall-rivets *and closing the elements from test body*	150	36.52	0.243	1.27	24.34	0.811	2.434	1.622	15

4. CONLUSIONS

From the above for determining the bending strength of the angular fixed connection just by gluing for together of the elements of wood panels made of wood particle, with adhesive and rounded wood wall-rivets for connection the elements from test body for examination by opening and closing elements, can bring the following the next conclusion:

1. Angled fixed connection only by sticking of elements made of wood panels of wood particle, for testing with the opening the elements of the test bodies, have strength of bending Msr=464 Nm Nm,
2. Bending strength of the angular fixed only by sticking together the elements made of wood panels of wood particle, for testing closing of the elements of the test bodies have Msr=161 Nm .
3. Angle fixed together with sticking and rounded wood wall-rivets for connection of elements made of wood panels of wood particle, testing with opening the elements of the test bodies have flexural Msr=367,6 Nm.
4. Angle fixed together with sticking and rounded wood wall-rivets for connection of elements made of wood panels of wood particle, testing with closing the elements of the test bodies have flexural Msr=150Nm.

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WATER IMPACT ON THE CHANGE OF THE PHYSICAL CHARACTERISTICS OF MULTILAYERED CONSTRUCTIVE PLYWOOD

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ABSTRACT

The paper elaborates the water impact on the change of the physical properties of multilayered plywood for use in construction. The water impact is analyzed in controlled laboratory conditions through the change of dimensions of the test specimens (length, width and thickness), volume, density, thickness swelling and water absorption in the period of 24 to 1248 hours. Experimental laboratory panels are made of structural beech and pine veneers. The veneers are glued with phenol-formaldehyde resin. The panels' surfaces are protected with phenol-formaldehyde foil.

The results from the research showed that the panels are characterized by uniform density, stability in volume, without any deformation of the shape and dimensions of the test specimens. The changes of the properties in the analyzed period are proportional to the change of the duration of the treating period of the test specimens. The panels have dimensional stability and meet the requirements of the standards for load-bearing panels for use in construction.

Keywords: multilayered plywood, physical properties, changes of physical properties, water resistant, dimensional stability

1. INTRODUCTION

Worldwide, plywood takes a great percentage of the total world production of wood-based panels. This is due to the fact that these panels with their characteristics and properties still cannot be replaced by other types of panels that are cheaper and have similar characteristics to plywood. On the other hand, plywood made with surface protection (protection for water impact, increased humidity and weather condition) still is indispensable product in construction, shipbuilding and automotive industry. These facts give the plywood production promising development.

Beside the fact that the plywood is very stable material during exposure to the effects of air moisture, water and weathering, a special attention is being paid to their production in order to improve their physical and mechanical properties. These panels are constantly subjected to researches in order to produce stable panels that can meet the modern exploitation requirements [1, 2, 3, 4, 7, 8].

The wood specie used for veneer production has no less significant impact on the plywood properties. The wood specie transfers its positive characteristics on plywood, but also it should be noted that its negative characteristics reduced the plywood properties. This means that it is important to know the quality of the wood raw material that will be used for veneer production.

Today, the researches into a field of plywood are made in order to produce dimensionally stable panels that can meet the modern exploitation requirements. From the aspect of improving their properties, special attention is paid on research of hygroscopic properties and their impact on the dimensional stability of the panels. The hygroscopic properties have impact on other plywood properties. Variations of hygroscopic properties cause variations in other properties of the panels, which reflect on the quality of the panels and their use value [2, 3, 4, 6]. Therefore, in modern plywood production special attention should be paid on wood specie for veneer production, the type and the properties of the resin for veneer bonding, as well as on the methods and standards for determination of the hygroscopic properties of the panels.

2. METHODS OF THE EXPERIMENTAL WORK

The aim of the conducted researches is studying the water impact on the physical properties of different types of multilayered plywood during prolonged treatment of water. The water impact is analyzed on standard test specimens in controlled laboratory conditions trough the change of the density, thickness swelling and water absorption.

The research is made on laboratory experimental seven-layered and nine-layered waterproof plywood made of constructive (peeled) veneers from beech and black pine with thickness of 1,5, 2,2 and 3,2 mm. The veneers are bonded with standard liquid phenol formaldehyde resin with the following characteristics: content of dry matters 47,3 %, viscosity by Ford (F4/20°C) 155 s, pH 11, density at 20°C 1,2 g/cm^3, resin curing temperature from 120 to 200°C, time of curing at temperature of 150°C from 20 to 35 s. The adhesive compounds have the following ratio: resin 72,46 %, filler (wheat flour) 10,87 %, water 10,14 % and catalyst (NaOH 20 % concentration) 6,52 %. The panels are made by combining the veneers with different thicknesses and by positioning the adjacent sheets at right angles. The surface finish is made of phenol-formaldehyde foil with surface weight of 120 g/m^2. This protection layer is impregnated into the surface veneers during the process of panel pressing. The prepared glue is spread on both sides of veneers with thickness of 3,2 mm in seven-layered panels and on veneers with thickness of 2,2 mm in nine-layered panels in quantity of 180 g/m^2.

The panels are made in single-opening electric press with the fallowing technological parameters: specific pressure of 18 kg/cm^2, pressing temperature of 155°C and pressing time of 20 minutes for seven-layered and 25 minutes for nine-layered panels. The dimensions of the panels are 580×580 mm. The equilibrium moisture of the panels is 8,14 %.

According to the type of veneer used for the panels, the following models are made:

- Model I: seven-layered panel made from beech veneers, d=16 mm, ρ=744,77 kg/m^3;
- Model II: nine-layered panel made from beech veneers, d=19 mm, ρ=747,27 kg/m^3;
- Model III: seven-layered panel made from black pine veneers, d=13 mm, ρ=744,58 kg/m^3 and
- Model IV: nine-layered panel made from black pine veneers, d=16 mm, ρ=741,26 kg/m^3.

The patterns of the panels are shown in Figures 1 and 2.

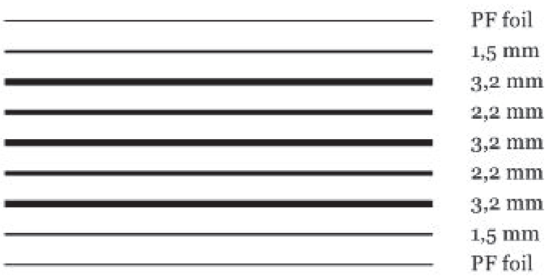

Figure 1. *Pattern of seven-layered panels*

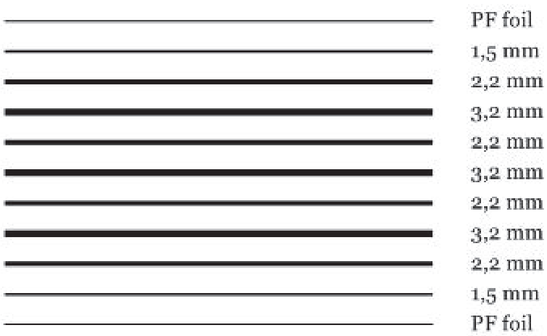

Figure 2. *Pattern of nine-layered panels*

The test specimens for research and analysis are made according to the national standard for wood-based panels MKS D.C8.100 [5]. Test specimens with standard dimensions of 100×100 mm are made from the panels. Six test specimens for conducting laboratory research from each model are taken.

During the laboratory research, the length and the width of the test specimens are measured with digital schubler at the middle of the test specimens at one measuring point for the length and one for the width, with accuracy of the measurements of 0,01 mm. The thickness of the test specimens is measured at five measuring points with mechanical comparator with accuracy of 0,01 mm. The weight of the test specimens is measured with digital weighing machine with accuracy of measurements of 0,01 g. The treatment of the test specimens in water regime is made by their full immersion in distillated water in special bath, continuously in the period of 1248 hours. The water temperature during the whole treatment was within the limits of 19 to 22°C.

The criterion for evaluation of hygroscopic characteristics and dimensional stability of plywood is the change of the properties that have a direct impact, i.e. change of the density, change of the volume, change of the thickness swelling and the change of water absorption. The changes of these properties are conduct by control measuring in intervals of: 24, 48, 72, 96, 144, 192, 288, 384, 576, 768, 1008 and 1248 hours.

The researches of the changes of density, humidity, thickness swelling and water absorption are made in accordance with national standards: MKS D.A8.062/85, MKS D.A8.064/85 and MKS D.C8.104/83.

3. RESULTS FROM THE EXPERIMENT AND ANALYSIS

The results from the research of the changes of density, volume, thickness swelling and water absorption of plywood are shown in Tables 1, 2, 3 and 4 and in Figures 3, 4, 5 and 6.

Table 1. *Values for the change of the density for the period of 0 to 1248 hours*

Model	Initial value (0 hours) [kg/m^3]	Value after 24 hours [kg/m^3]	Final value (1248 hours) [kg/m^3]	Difference as absolute value [kg/m^3]	Difference in relatuve units [%]
I	744.77	888.48	1042.36	297.59	39.96
II	747.27	886.31	1041.92	294.65	39.43
III	744.58	832.78	964.39	219.81	29.52
IV	741.26	820.91	961.52	220.26	29.71

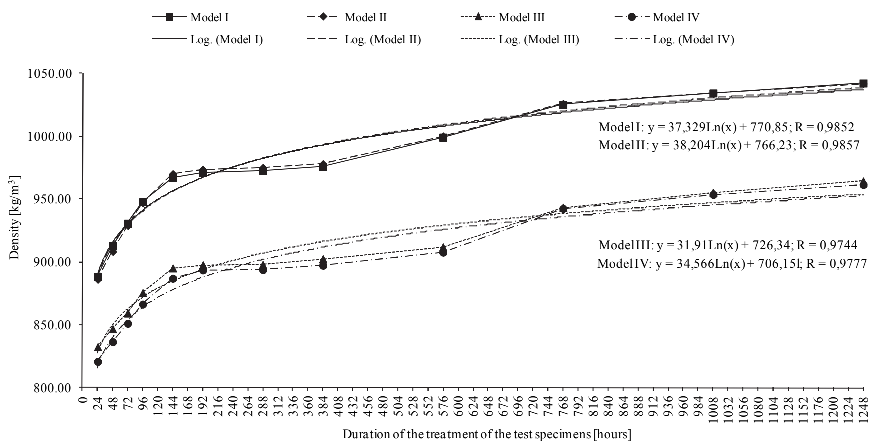

Figure 3. *Increase of the mean arithmetical values of density for period of 24 to 1248 hours*

The results from the research of the change of density shows a tendency of increasing of mean values in all models for the analyzed period. Increasing of the mean arithmetical value is proportional to the increasing of the duration of the treatment of the test specimens. In all models the increasing of the values is intense in the initial period of treatment whereupon the maximal value is achieved in the final control measuring. This tendency is noticed in all models.

The change of the density in all models in analyzed period expressed in absolute values is 297,59 kg/m^3 in model I, 294,65 kg/m^3 in model II, 219,81 kg/m^3 in model III and 220,26 kg/m^3 in model IV. The difference between the initial and final values expressed in relative units is as follows: 39,96 % in model I, 39,43 % in model II, 29,52 % in model III and 29,71 % in model IV (Table 1, Figure 3). The analysis of the results shows that higher density is achieved in models made of beech veneers in comparison with the models made of black pine veneers.

The analysis of the results from the research of volume changes shows a tendency of proportional increasing of the mean values in analyzed period in all experimental models. The increase in volume, as well as the other properties is intense in the initial period of treatment. After that, the mean values are increasing with lower intensity, whereupon the maximal value of the volume is achieved in final control measuring.

The change in volume in all models in analyzed period expressed in absolute values is within the limits of 14,74 cm^3 in model I, 17,95 cm^3 in model II, 22,01 cm^3 in model III and 23,59 cm^3 in model IV. The difference between the initial and final values expressed in relative units is as follows: 9,50 % in model I, 9,35 % in model II, 17,41 % in model III and 14,60 % in model IV (Table 2, Figure 4).

The results from the research of relative thickness swelling in all models for the analyzed period shows a tendency of proportional increasing of the arithmetical mean values. In all experimental models the thickness swelling is increasing proportionally to the increasing of the duration of the treatment of the test specimens.

The change of the relative thickness swelling of the models in the analyzed period expressed in absolute values is 2,23 % in model I, 2,69 % in model II, 4,76 % in model III and 5,03 % in model IV. The difference between the initial and final values expressed in relative units is as follows: 37,93 % in model I, 50,66 % in model II, 41,90 % in model III and 58,90 % in model IV (Table 3, Figure 5). This means that higher thickness swelling is achieved in models made of black pine veneers (model III and IV) in comparison with models made of beech veneers (model I and II).

According to the standard MKS D.C5.032 that for different wood-based panels defines the maximum value of 12 % for relative thickness swelling for treatment of 24 hours, it can be concluded that analyzed models for treatment of 24 hours meet the requirements of this standard. According to this, it can be concluded that plywood are dimensionally stable under water impact, which is one of the requirements for their application in conditions of increased humidity and weather conditions. The obtained research results of thickness swelling for the period of 24 hours corresponds with the results of similar investigations known in professional literature [2, 3, 4, 6].

The research results of relative water absorption in all models for the analyzed period shows a tendency of proportional increasing of mean arithmetical values. The water absorption of researched models is increasing proportionally to the increasing of the duration of the treatment of the test specimens.

The change of relative water absorption in all models for the analyzed period expressed in absolute values is as follows: 26,51 % in model I, 27,14 % in model II, 27,22 % in model III and 28,20 % in model IV. The difference between the initial and final values expressed in relative units is as follows: 99,07 % in model I, 107,10 % in model II, 109,19 % in model III and 137,70 % in model IV (Table 4, Figure 6). The results shows that water absorption for the analyzed period in models II, III and IV exceed the limit of 100 %, while in model I is at the limit of 100 %.

From the conducted researches a general statement can be made, according to which the change of the physical properties for the analyzed period runs proportionally to the change of the duration of the treatment of the test specimens, i.e. the analyzed property is proportionally increasing with the increasing of the duration of the treatment. The dynamic of the change of the mean arithmetical values of the physical properties in the period of 24 to 1248 hours in all models runs according to the logarithmic function $y = aLn(x) + b$. The coefficient of correlation between the calculated and theoretical values in all models is particularly high, mostly above 0,95 (total correlation according to

Roemer-Orphal scale). In some models for certain physical property, the calculated and theoretical values are almost the same, with the coefficient of correlation above 0,99.

Table 2. *Values for the change in volume for the period of 0 to 1248 hours*

Model	Initial value (0 hours) [cm^3]	Value after 24 hours [kg/m^3]	Final value (1248 hours) [cm^3]	Difference as absolute value [cm^3]	Difference in relatuve units [%]
I	155.12	164.80	169.86	14.74	9.50
II	191.92	202.82	209.87	17.95	9.35
III	126.39	141.15	148.40	22.01	17.41
IV	161.59	175.75	185.18	23.59	14.60

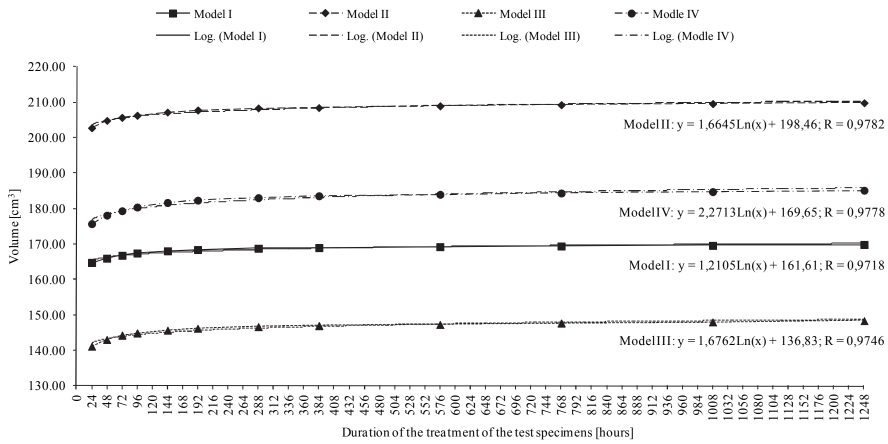

Figure 4. *Increase of the mean arithmetical values of volume for period of 24 to 1248 hours*

Table 3. *Values for the change of relative thickness swelling for the period of 0 to 1248 hours*

Model	Initial value (24 hours) [%]	Final value (1248 hours) [%]	Difference as absolute value [%]	Difference in relatuve units [%]
I	5.88	8.11	2.23	37.93
II	5.31	8.00	2.69	50.66
III	11.36	16.12	4.76	41.90
IV	8.54	13.57	5.03	58.90

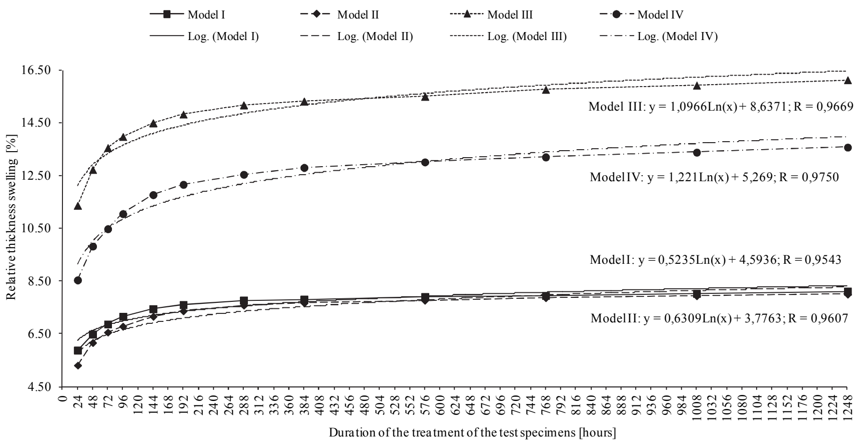

Figure 5. *Increase of the mean arithmetical values of relative thickness swelling for period of 24 to 1248 hours*

Table 4. *Values for the change of relative water absorption for the period of 0 to 1248 hours*

Model	Initial value (24 hours) [%]	Final value (1248 hours) [%]	Difference as absolute value [%]	Difference in relatuve units [%]
I	26.76	53.27	26.51	99.07
II	25.34	52.48	27.14	107.10
III	24.93	52.15	27.22	109.19
IV	20.48	48.68	28.20	137.70

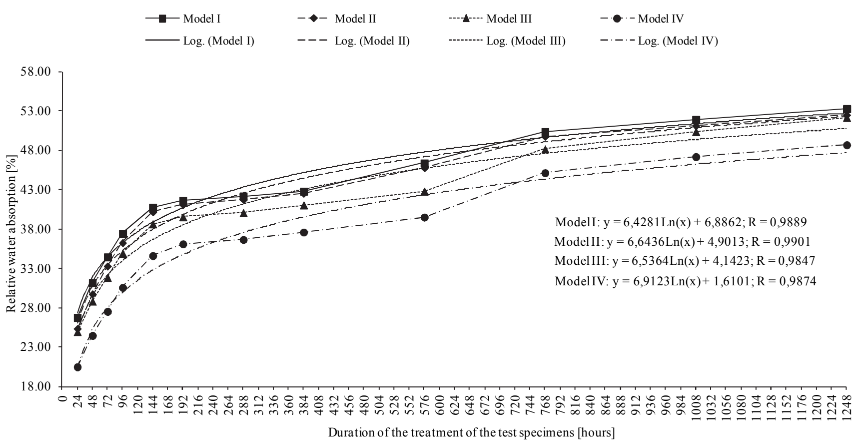

Figure 6. *Increase of the mean arithmetical values of relative water absorption for period of 24 to 1248 hours*

4. CONCLUSIONS

On the base of conducted researches the following major conclusions can be drawn:

1. The researches of the change of the physical characteristics of different types of multilayered waterproof plywood showed that stable panels are made, with a stable density and humidity, which is a requirement to perform standard research and analysis. Test models are characterized by uniform density over the entire surface of the panel, stable volume without presence of deformation of the dimensions and form of the test specimens.

2. At all investigated models a general conclusion is find for the change of physical properties in analyzed period. The change of the physical properties in the analyzed period runs in proportion with the change of time of the treatment of the test specimens, i.e. the value of the analyzed property increases proportionally as the time of treatment of test specimens is increasing.

3. The panels showed good results from the aspect of the dimensional stability. They are dimensionally stable and according to the tested physical properties meet the requirements of the national standards for use as structural panels in wooden constructions. The values from the research for the thickness swelling showed that the connections in the wooden constructions made from these panels exposed on extreme and prolonged water impact will not suffer serious deformations and displacements, which is the basic requirement for panels' structural use in constructions.

4. Analyzing the results from the research, it can be concluded that in experimental models for the analyzed period of treatment of 1248 hours the maximum value of the physical properties is not achieved, i.e. the values still have increasing tendency. The maximum value of the certain physical property can be defined only by continuing the experiment in the period of time over 1248 hours.

5. These studies have scientific and practical meaning. They can help in selection of materials, technology and technological parameters for production of multilayered water-resistant plywood, in order to develop dimensional stable panels for use in conditions of increased humidity.

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747.012:616.894-053.8

CONSIDERATION OF COLOUR AND INTERIOR DESIGN FOR PREMESIES ASSIGNED FOR INDIVIDUALS SUFFERING FROM ALZEIMER'S DISEASE AND OTHER DEMENTIAS

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ABSTRACT

The most known problem associated with Alzheimer's disease (AD) and other dementias is the memory loss. However, the decline of the brain activity to process visual information is also profound. Therefore, using this information the interior design becomes a powerful tool to improve the quality of life to the individuals suffering from such diseases.

The aim of this study is to explore how modification and design of the environment using simple tools such as color, light and furniture layouts can help patients into maximizing their capacity for independent functioning.

Key words: color psychology, interior design, environmental orientation, patients

1. INTRODUCTION

Living with dementia, especially with AD, is hard not only to the person who suffers from the disease, but also to all of his close family members. Keeping on mind that the disease is progressive, it makes it even more difficult to the handle all the pressure and give the required care that is needed by the patient. The institutionalizing becomes necessary at some point of the illness. Even though AD is incurable disease we cannot say that is not "treatable" by designing the space they would live in, ensuring that the patients would have acceptable quality of life. The physical space that is designed to: promote safety, help orienting, stimulate activity, reduce frustration and anxiety can be ideal residence for AD patients.

Having the knowledge on how to make a better place for people suffering from these diseases is one step forward to better quality of life, not only patient's life, but also to their loved ones.

The goal of this study is to affect into maximizing the independence of the patients by practical implementation of the instruments for designing such facility and reducing the negative design. A thing to consider prior building this type of institutions, is that the collaboration between architects, designers and nursing should be expanded in order to promote better understanding of the needs of the patients.

1.1 Impact of color towards people

Color as an element in designing, has its own influence upon the observer. The influence could be: physiological and psychological. The ancient Greeks knew the psychological impact of the color, and it is referred towards its therapeutic use in medicine – chromo-therapy. How the individuals react on colors is important and it should be considered prior designing so the effect would be positive and pleasant. The color has the power to awake emotional responses related to the past experiences and cultural background, most of the time the psychological impact of the color is a product of associations. Therefore, it is not possible to determine which colors would be ideal to design facility for patients suffering from dementia, because of that, the color is used to increase visibility by contrasting it with the objects.

1.2 Dementia and Alzheimer's Disease

Dementia is a disease followed by serious loss of global cognitive ability. Although this state might be expected by normal ageing, it also might be condition which is a result of unique global brain injury, damage or disease of the body.

Most often dementia is found on elderly population, but it also can be occurred before the age of 65 (early onset dementia). It is not a single disease but a non-specific syndrome. Some of the symptoms affect the loss of memory, attention, language, problem solving, it reduces the ability to learn, to reason, causes disorientation in time, place and person.

Alzheimer's disease is the most known form of dementia. It causes degeneration of brain tissue in various parts of the brain and it is mostly diagnosed in people over the age of 65. Mainly the disease is divided in four stages of development: pre-dementia, early stage, moderate and advanced stage. Although AD manifests and develops differently for every patient, there are many common symptoms such as: memory loss, confusion, irritability and aggression, mood swings, trouble with language and long term memory loss. As the disease reaches its advanced stage, bodily functions are lost ultimately leading to death.

Bearing in mind that an AD patient suffer such cognitive losses, means that the loss of a sense of self, visual, spatial and temporal disorientation, go along with the identity crisis which can be very profound. Inability to recognize familiar objects, places, even the home they live in means the loss of the sense of home, a need that every human has to fell one with the environment.

One of the typical problems that AD patients face is the strong anxiety, result of their inability to understand the world surrounding them. These patients have their own sense of present and live in this present with strong emotional affect. Living in this eternal present must be taken into account and even respected however difficult it is to decode. Keeping this in mind, the role of architecture and design is to interpret the details, the special and unusual needs of people who have lost their relationship with the world they use to know, and to help them regain it by creating new and different channels to communicate in line with their residual ability of understanding.

2. MATERIALS AND METHODS OF RESOLUTON

2.1 Dementia patients and institutionalizing

Knowing that patients suffering from dementia and Alzheimer's disease lose spatial orientation and have severe memory losses, changing their setting and forcing them to deal with new unfamiliar people and environment can sometimes worsen the situation. Recent studies have shown that, at similar stages of the disease the death rate for institutional patients is 19% higher than the patients being cared for at home. However, Alzheimer's is a progressive and chronic disease which eventually, at some given stage of illness makes it necessary and even inevitable for the patient to be institutionalized.

2.2 Using color contrasting in institutional environment

As already mentioned above, it is not really possible to determine which color would be ideal for creating same effect to every patient in an institution of this kind, but, the use of color is important for detection and identification of objects, for informational purposes and at least, surely, for aesthetic purposes. With old age follows common problems relating visuo-spatial disturbances. The visual perception of people living with AD is such that they have little or no ability to discriminate between foreground objects and near background, and also, they have little or no ability to focus on details, like doors when certain colors cover the surfaces. In normal conditions, perceptual information is not necessary and to some even sufficient, but having these problems and symptoms can really change the impact on the perception of environment.

By using it the right way, color can increase the visibility and change the way we perceive and act in our surrounding. When designing the dementia-friendly environment, most of the time the right way to use color would be by effective color contrasting. Elderly need about three times as much contrast as young people to find objects. Combination of light colors from the middle of the spectrum like yellow or green, with dark colors from either end of the spectrum like red or blue, is used for most effective contrasts. In the case when similar color as the objects is used in the background of it, gives the "camouflaged" effect, and makes the object look less visible, so this type of using color should be avoided when designing this kind of premises.

***Figure 1**. Common room, furniture with contrast color from other surrounding.*

Use of the color is important for informational purposes like sign system and for way-finding. For the informational purposes, the cues and signs have to be contrasting in color, to be able to draw attention, and with simple explanation.

Doors and fixtures should be outlined with contrasting color in order to be visible as mentioned above. This helps people to move with more confidence, reducing confusion and agitation.

***Figure 2.** Outlining of doors and signs*

***Figure 3.** Outlining of doors and contrasting rails*

2.3 Use of light in dementia-friendly design

When designing such facilities, it should be paid special attention to the lighting because, it has such great impact on care. Good lighting solutions can improve way finding, help carry out daily activities and reduce the falls. It also helps effective color contrasting. The amount of natural daylight should affect color visibility and therefore should affect the color choice and choice of artificial light. Natural light improves the physical well-being, helps with vitamin D synthesis and calcium absorption. Having natural light inside provides in environmentally sustainable design, and it also reduces energy costs, so this means, that the best lighting method brings natural light inside.

To create an environment with sufficient lighting means making balance between the natural and artificial light to even up the light levels, and getting rid of glare when needed. Designing lighting system is complicated and there are more factors that need to be considered for good quality lighting such as: efficiency of fixtures, absorption of surfaces, the size of the layout of the area, reflection of surfaces, direction of lights, color of temperatures etc.

2.4 Fixtures and fittings

Another important part for the design of these types of facilities, especially for the way-finding is the choice of fixtures. They have to be comfortable and easy to use. Hand rails are mandatory, it is recommended that they are oval in shape, with non-slip material such as wood, contrasting the background with the color and strong for supporting. Handles on the doors are more recommended than door knobs, because they are easier to use, also C-shaped cupboard and wardrobe handles are often recommended.

Fixtures and fittings for bathroom are crucial for practical purposes. They have to be easy to find and use, and also less stressful for staff. Some of the fixtures in the bathroom on some occasions may be used for unintended purposes by people suffering from dementia, for example, a towel rail can become a grab rail, so it is important that these types of fixtures are strong enough to take that kind of weight.

Also important part of creating dementia-friendly environment is well designed sign system which is simple for understanding, easy to notice and with big clear letters. It would be also helpful to have some reference objects inside the premises.

2.5 Furniture

It is mentioned earlier how important it is for people that suffer from Alzheimer's disease to feel like home, and the furniture is what makes the environment feels most like a home. Using patient's personal furniture is part of the environmental memory cues that could be used for memory jogging alongside with other cues such as: photos of place where the person has lived, photos of family and other personal objects.

Figure 4. *Patient's private bedroom*

Figure 5. *Hallway of the institution.*

This way of designing the environment enhances the independence and contributes to improve the patient's functioning. For people whose cognitive mapping ability has been compromised by brain dysfunction, naturally mapped environment with visible key places such as dining rooms, bathrooms and common living rooms gives them opportunity to find their way to desired destination instead of wander. Greater bedroom places which are more private and personalized can reduce the anxiety and aggression, and well-designed spaces encourage family members to visit more often.

The furniture used in these facilities should have round edges, color contrasted to the background, it should be comfortable and reflect personal warmth. In the common rooms should be avoided over accessorizing, but rather keeping the simple home-like layout. The placement of furniture affects how it is used, for example, different table and chairs layouts can help promote sociability, suggest a quiet spot during mealtime or other activities. People suffering from dementia and Alzheimer's disease tend to sit for a long periods of time, so the comfort and sense of familiarity are crucial when choosing the chairs.

Tables made out of wood are likely to appear warm and familiar to most people. In dining rooms, square tables are ideal and recommended because they give each person clearly defined eating space.

Some patients may require special designed beds, but for the rest, domestic beds are recommended for the home-like environment.

Various use of patterns and textures in the common rooms help people to distinguish different areas in the facility. With the purpose of reducing social withdraw; these facilities should contain limited number of common spaces, each with a unique character. On the other hand, physical and verbal agitation does not appear to be affected by environmental design.

2.6 Flooring

When considering floor materials, we need to think about their long-term benefits: resilience, compactness, sustainability and durability. Carpets and resilient floors look good, they are quiet, have soft surface, reduce glare and are more home-like, therefore they can be used for common areas and personal rooms. Resilient floor materials have non-slip surface, non-reflective finish, they are stain resistant and easily cleaned, and so they are good for wet areas such as bathrooms and even hallways. Resilient floors come in various thicknesses and colors, and are suitable for people with mobility issues and people on wheelchairs.

On the spot where two different materials of the floor meet, is recommended to be used same or similar color to encourage movement from one area to another, and on the other hand, use of contrasting color on floor discourages movement and can be used for places intended for staff. Considering safety it is important the steps in the facility to have clearly defined edges, and all of the rooms, personal and common, to be on same level.

2.7 Outside space

Another thing to consider when designing the space for people suffering from AD is that they tend to wander, so the exit of the premises are supposed to be discreet and unobtrusively placed. But their outdoor freedom should not be cut out, contacts with nature could be beneficial to people with dementia. These types of facilities should consider investing into gardens that are easily accessible. Gardens are useful for stimulating the senses, and are ideal for therapeutic purposes, also having plants and pets around stimulate the sense of responsibility. It is recommended that the windows from common rooms are faced towards the garden so it would remind patients that the gardens are accessible, this increases their self-esteem and self-awareness. Gardens must be designed for ease of movement, with resting places and reference point for orientation, they have to be completely safe because of the tendency to wander, it is good idea to have continuous path that leads back to the building, in a way that is discreet and way-finding.

3. CONCLUSION

In conclusion I would like to point out again the importance of collaboration between architects, designers and nursing when creating an environment for people suffering from these diseases.

The environment for sure can influence the patient's behavior whether it can compensate for losses or can, contrary, accentuate the cognitive losses. Though changing the environment may not change the course of the disease, it may well reduce the behavioral problems, and may prolong patient's functional capabilities. Having the knowledge and implementing it practically means smart and sustainable design, and most important, better life for patients.

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INVESTIGATION FOR CHARACTERISTICS OF STRENGHT, FOR ANGLE CONECTION IN CONSTRUCTION OF ELEMENTS FOR KITCHEN MADE OF OSB - BOARDS

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ABSTRACT

Due to the application of everyday use of OSB - panels as structural elements in the design of furniture and interiors in showrooms in housing to bars and other places, the question of structural properties of OSB - boards embedded in elements of furniture and interiors.

The main objective in this paper is the study and determination of the bending strength of the fixed structural connections why are used in the construction of structural elements of a kitchen made from OSB-plates. Made the test fixtures for testing with opening and closing elements of OSB-plates and incorporating structural relationships to form elements in the test fixture.

When it is used the following structural connections relationships such as:
-only OSB panel boards for construction and connection to forming test body with using glue and
-only OSB panel boards for construction and connection with wood rounded wall-rivets (inlays of wood) and sticking. Due to the application of everyday use of OSB - boards as structural elements in the design of furniture and interiors in showrooms in housing to bars and other places, the question of structural properties of OSB - boards embedded in structural elements of furniture and interiors. This paper and compared the data obtained are shown in relation to investigations by other authors on similar issues and using the accompanying methods and standards of the EU for furniture connections in wood industry. Methods who are used the are by Kjuchukov and BDS-Bulgarian State Standards that are part of the European standards.

OSB-plates are manufactured by manufacturer Kronospan, model Kronospan OSB-third Used OSB - boards are made of softwood, long and thin chips, who are oriented for three smooth layers (average dimensions sprinkle the chips are 95 mm / 0,65 mm).

Key words: strength, bending test , OSB - boards, element, body, furniture, interior sticking, rounded wood rivets (inlays of wood), power bending, deforming point bending.

1. PREVIOUS RESEARCH

The literature that was available to us we can bring forward some considerations that are important to mention here, and that is that we using several recognized methods for constructive connection and determination of strength of bending in compositions for corpus furniture. Some authors are concerned with testing the bearing capacity of the construction of furniture, burdened with the deforming forces acting on purpose bulky product. The exercise of these tests requires special equipment and machinery larger than the dimensions of the furniture. However, in reality complicates of the problem of testing and getting the real dimensions for test body, and that these tests are very expensive, and thus test and would be unjustified. Therefore, scientists from the field of scientific research continued to find new methods to study the strength of structural compositions.

By studying the literature, we found that our conditions of scientific work in the field of strength of structures of furniture is best to choose the classical way of determining the strength of some constructive connections through experimental means of testing the strength of connections according to the method of Kjuchukov, which are presented as BDS - Bulgarian state standards (14, 15, 18, 23, 24, 25, 26, 27, 30, 32, 35, 39, 41, 42, 43, 44, 82 , 90);

Similar tests were conducted in Germany by Albin (57), Kuhne (96), Rinkefeil (107). In Poland, the authors: Grosman (77), Hassler (78), Voiculesku (113), Korolev (9) Janson and Kaszan (80), Metrek (103) and Truzewiez (110,111). In America Eckelman (64,65,66,67,68 and 69).

2. PURPOSE AND METHOD OF EXAMINATION

The main objective of this paper presents the determination of the strength of the bending, for connection who are used in constructions of furniture for kitchen made of OSB panels. Frequently used angle connections are fixed and montage- de montage links:
-just with glue and
-with glue and with rounded wall-rivets for wood.

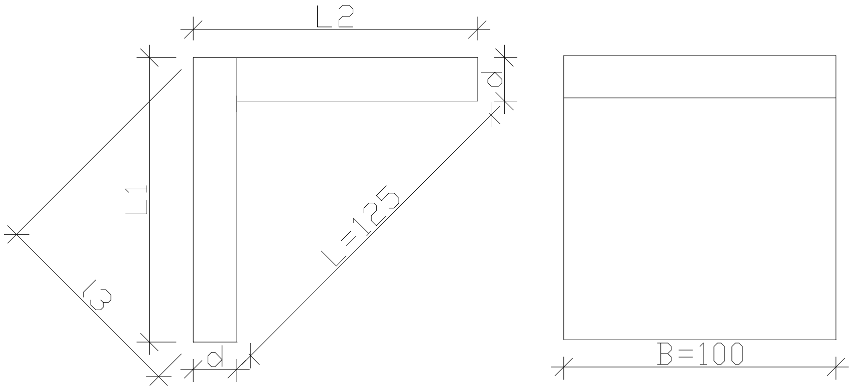


Figure 1. *Dimensions of test fixtures*
L - distance between the inner edges of the test body; L1 - length of the longer element of the test body; L2 - length of the test body; B - width of the test body; l3 - a distance that determines the length of the outer edge of the line that passes through outer edges of the test body; d - thickness of the elements of the test body.

As a basic material for making angular compositions selected OSB boards manufacturer Kronospan, model kronospan OSB third. The plate is oriented chips and is made from 100% softwood (Abies alba), long and thin chips transversely oriented in three layers and the average size (95mm / 0,65 mm). These plates Kronospan to European Norms EN 312 and Class E1 and BDS 5508th.

The choice of rounded wall-rivets for wood, conjunction element is under Kjuchukov methods and is shown in Figure 2.

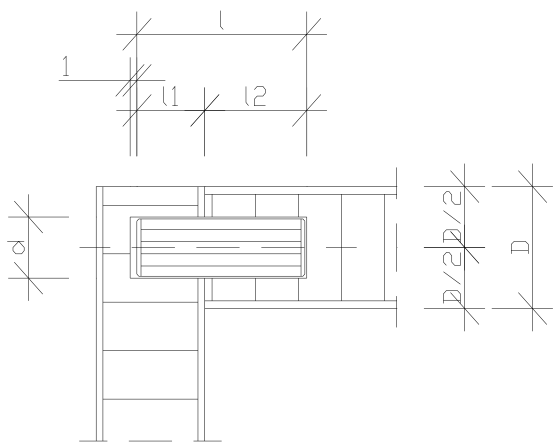
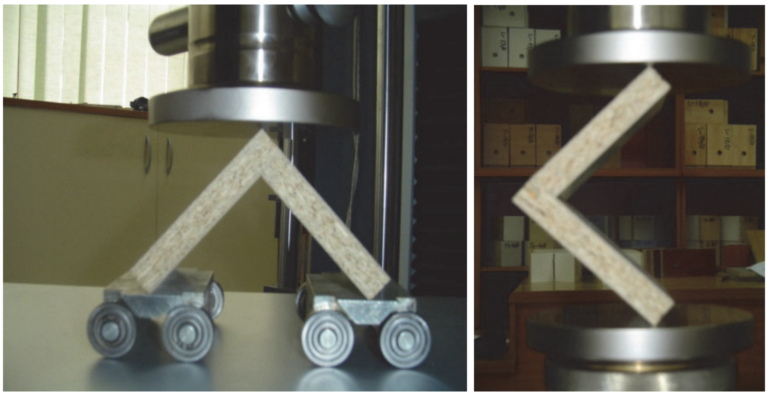


Figure 2

The elements of the test fixture with are thickness of 16 mm, and according to them rounded wall-rivets for wood are selected with the following dimensions: thickness d = 8mm, and the length l = 25mm. As the tool, used is single component waterproof adhesive Chromos Drvofix VO tip-3, made on the basis of polivinilacetat water dispersion. Purpose of putting materials that are exposed to sun or humidity short-acting water of which requires about D3 connection.

Characteristics of glue: PH value: 2,0-3,0 (DIN 53 785) Viscosity: 14000 ± 4000 m Pas (RVT ISO 2555, B6/20/23 ° C); Contents of dry matter: 54 ± 1 (DIN 53,189) Density: 1035-1045 kg/m3; optimum operating temperature: 20 ± 5 ° C.

In Figure 3, shows how the experimental investigation of test bodies in the universal testing machine. Test body is burdened with the forces of bending and it is examined by opening and closing elements.



a. Investigation by opening the elements b. Test closure elements

Figure 3. *Test method for test bodies in Kjuchukov*

3. DISCUSSION

Bending strength expressed through the middle value of bending the corner fixed connection only by sticking of the elements of OSB panel boards with the opening of elements from test body, the are value for strength of bending 55,70 Nm (see Table 1).

Table 1

N^0	Corner connection	Strength of bending Nm	S Nm	V %	Sr Nm	p %	n бр.
1	2	3	4	5	6	7	8
1	only by sticking	55,70	1,5	0,269	0,0387	0,7	15

Deformation of the test body with a fixed angles connections for composing of OSB - elements in the investigation with opening of elements are shown in the Figure 4.

Figure 4.

Bending strength expressed through the middle value of bending the corner fixed connection only by sticking of the elements of OSB panel boards with the closing of elements from test body, the are value for strength of bending 65,69 Nm, in Table 2, are given and other values of various statistics.

Table 2

N^0	Corner connection	Strength of bending Nm	S Nm/m	V %	Sr Nm/m	p %	n бр.
1	2	3	4	5	6	7	8
1	only by sticking and close the elements	65,69	3,85	5,86	0,99	1,51	15

Deformation of the test body with a fixed angles connections for composing of OSB - elements in the investigation with closing of elements are shown in the Figure 5.

Figure 5

Bending strength expressed through the middle value of bending the corner fixed connection by rounded wall-rivets for wood and sticking of the elements of OSB panel boards with the opening of elements from test body, the are value for strength of bending 79,10 Nm (see Table 3).

Table 3

N^0	Corner connection	Strength of bending Nm	S Nm	V %	Sr Nm	p %	n бр.
1	2	3	4	5	6	7	8
1	with sticking and wood rounded wall-rivets, and opening the elements from test body	79,10	2,54	3,21	0,65	0,82	15

Deformation of the test body with a fixed angles connections with sticking and rounded wall-rivets for wood for composing of OSB - elements in the investigation with opening of elements are shown in the Figure 6.

Figure 6

Bending strength expressed through the middle value of bending the corner fixed connection by rounded wall-rivets for wood and sticking of the elements of OSB panel boards with the closing of elements from test body, the are value for strength of bending are 86,5 Nm / m, in Table 4 are given and other values various statistics.

Table 4

N^0	Corner connection	Strength of bending Nm	S Nm	V %	Sr Nm	p %	n бр.
1	2	3	4	5	6	7	8
1.	with sticking and wood rounded wall-rivets, and closing the elements from test body	86,5	2,31	6,27	0,59	1,62	15

Deformation of the test body with a fixed angles connections with sticking and rounded wall-rivets for wood for composing of OSB - elements in the investigation with closing of elements are shown in the Figure 7.

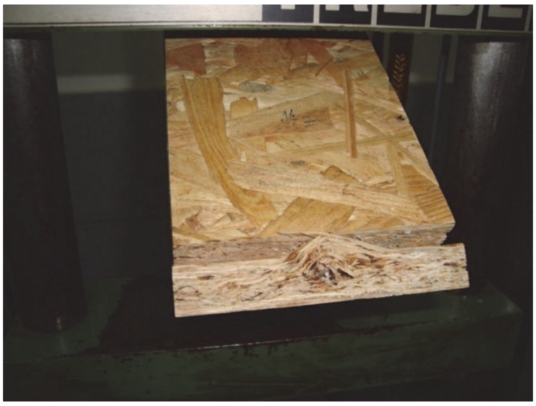


Figure 7

4. CONCLUSIONS

From the above for determining the bending strength of the angular fixed compositions just with glue for gluing of the OSB elements in test body and angular fixed composition ,with rounded wall-rivets for wood, for connection the OSB elements and with examination of opening and closing of elements from the test body, can bring the following conclusions:

1. Angle fixed compositions only by sticking for connection the OSB elements in test body, for testing with the opening the elements of the test bodies, have strength of bending Msr = 55,70 Nm,

2. Angle fixed compositions only by glue sticking for connection the OSB elements in test body, for testing with the closing the elements of the test bodies, have strength of bending Msr = 65,69 N.m.

3. Angle fixed compositions only by sticking for connection the OSB elements in test body, for testing with the closing the elements of the test bodies, have strength of bending for value 15,20%, from the angle fixed compositions only by sticking for connection the OSB elements in test body, for testing with the opening the elements of the test bodies.

4. Angle fixed compositions with rounded wall-rivets for wood and gluing for connection the OSB elements in test body, for testing with the opening the elements of the test bodies, have strength of bending Msr = 79,10 Nm .

5. Angle fixed compositions with rounded wall-rivets for wood and gluing for connection the OSB elements in test body, for testing with the closing the elements of the test bodies, have strength of bending Msr= 86,5 Nm.

6. Angle fixed compositions with rounded wall-rivets for wood for connection the OSB elements in test body, for testing with the closing the elements of the test bodies, have strength of bending for 8.55% much more for the angle fixed compositions with rounded wall-rivets for wood and gluing for connection the OSB elements in test body, for testing with the opening the elements.

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THE STRUCTURE OF FURNITURE SUBJECTED TO MECHANICAL TESTS ACCORDING TO THE METHOD OF USE – THE PERSPECTIVES OF DEVELOPMENT OF FURNITURE TESTS

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ABSTRACT

This paper presents the economic aspects resulting from the furniture testing process, such as: benefits for furniture factories, benefits to the domestic economy, as well as benefits for the final recipient, the customer.

Based on their laboratory furniture testing expertise, the authors present the issues of durability and strength tests of various furniture groups including the indication of factors that determine the quality of furniture. The trends in furniture production and the tendencies in furniture tests in 2000-2012 will be described, and the forecasts of development of testing in 2013-2020 shall be presented through the characteristics of factors influencing the economic situation.

Key words: Furniture, furniture tests, furniture strength, furniture safety, EN standards concerning furniture tests

Mechanical tests of furniture consist in subjecting furniture to loads and forces specified in EN standards. The loads have a static, singular or fatigue character. The tests simulate the use of a piece of furniture through the implementation of testing loads in a shorter time. Testing methods incorporate the following pattern: preliminary measurement, load, time under load, final measurement, evaluation according to normalised criteria.

The expertises are carried out in laboratories equipped with measurement and testing equipment that meets the standards of quality and accuracy of measurement required by the tests of: strength, stability, functional dimensions and structure safety.

EN standards as well as national regulations in the form of ordinances concerning the requirement to certify products constitute the legal basis of furniture testing.

According to the method of use, the furniture can be classified as follows:

- storage furniture (wardrobes, chests of drawers, cabinets),
- lying furniture (beds, mattresses, convertible sofas, bunk beds),
- seating furniture (chairs, armchairs, sofas, stools, high chairs),
- tables and desks.

Regular tests of prototype furniture have a good economic effect for the manufacturer. The manufacturer knows that the product that is marketed is of confirmed quality, it is safe and has the strength required by load of use.

This, in turn, contributes to the domestic economy, where the furniture sector can gain strategic importance, because a piece of furniture of confirmed quality becomes an export product that creates competitive opportunities on the continental and global market.

Also, a conscious customer, when deciding to purchase a piece of furniture, uses the quality criterion that is confirmed by a certificate, which gives him or her the guarantee that the structure is fault free, stable and safe to use.

The cost of testing a piece of furniture is, on average, about €500, which is not a considerable amount in comparison to the costs of complaints, withdrawing the defective product, or contractual penalties for failing to comply with the act on its general safety.

The furniture production trends are influenced by the economic situation, fashion, and also by the requirements of residential housing. In case of a limited living area which should be used to the fullest, the multi-purpose furniture gain importance because they enable conversion, e.g. sofa to bed, bed to cabinet with shelves, etc. Multi-purpose furniture must, therefore, meet the requirements of several corresponding standards: in case of beds – EN 1725, EN 1957; in case of sofas – *EN 1022, EN 12520, EN 1728,* in case of closets – *EN 14749.*

In 2013-2020 because of the need of creating factors that enable recovering from the global crisis, we can expect the growth of the financial services sector, which will be connected with the demand for office space. This will increase the demand for office furniture that will have to meet the following standards:

EN 12520 Furniture – Strength, durability and safety – Requirements for domestic seating

EN 15373 Furniture – Strength, durability and safety – Requirements for non-domestic seating

EN 1022 Domestic furniture – Seating – Determination of stability

EN 1335-1 Office furniture – Office work chair – Part 1: Dimensions – Determination of dimensions

EN 1335-2 Office furniture – Office work chair – Part 2: Safety requirements

EN 1335-3 Office furniture – Office work chair – Part 3: Test methods

EN 13761 Office furniture – Visitors chairs

EN 12727:2000 Furniture – Ranked seating – Test methods and requirements for strength and durability.

The factors increasing the demand are as follows: high quality confirmed by a certificate, interesting design, good quality of natural materials such as: wood or leather, multi-purpose use of furniture, availability in various colours and dimensions.

UDC 674

INCREASING THE EFFICIENCY OF WOOD RAW MATERIAL USING CNC EQUIPMENTS IN WOOD PROCESSING INDUSTRY

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ABSTRACT

The use of CNC machines is changing radically the furniture making industry. Time consuming techniques in the production process, such as cutting curves, became much easier. CNC machines are 'programmed' to perform several steps at a time, cutting down on the time required for human action. With the advent of wood based panel products such as particle board and medium density fiberboard (MDF), CNC equipment has now been widely adopted for the production of components for many types of furniture.

This study is focused in showing the advantages of the use of CNC equipments in furniture making industry in Albania. We have considered the processing of wood based panels for producing furniture parts using CNC machines in comparison to the traditional methods used up-to-now in a wood processing company.

The efficiency gains in production of "side elements" for wardrobes sized 2400 x 580 x 18 mm are measured in terms of production time, raw material quantity used and quality of the product and compared to the above mentioned elements resulting from the traditional production techniques. Production of "side elements" for wardrobes is done in a drilling CNC machine type "Biesse Rover 20", which is one of the CNC equipment used a wood processing company for production of furniture parts.

Saving in production time and raw material used results in decreasing costs per unit of production and the better quality of the parts gives the company a potential higher margin of profit per unit.

Key words: CNC equipments, furniture parts, time efficiency, cost decrease

1. INTRODUCTION

As in every field of industry, even in the furniture manufacturing industry, efficiency is a key factor which affects the performance of the firm activity. As such, it is aimed to increase the efficiency of using the time of labor and raw materials. By "using of time of work in the manufacturing process" is intended to achieve that stage of the technological process where the coefficient of utilization of machinery to be in such values so the machinery doesn't have idle time during working shifts and by "utilization of working time during the assembling process of finished wooden objects" is intended implementation of all necessary operations in such a way as to eliminate as many "minor works" of assembling from the assembling workforce. By "exploitation of raw materials" is intended reducing as much waste as possible (Black and Hunter, 2003).

The traditional production process and assembling of bedrooms include several processes as cutting, edge banding and fixing elements. Final assembling is a very long process in time, because the assembling workforce should carry out a series of measurements in a way such to achieve a accurate and qualitative assembling.

Today, with the introduction and use of numeric-controlled machinery (CNC) many production processes in the wood processing industry including the production of bedroom parts are revolutionized. Computerized numerically controlled (CNC) woodworking machinery can automatically control the movements of a spindle and table. Recently, CNC woodworking machinery has been widely introduced in wood industries for automatically cutting, drilling, and shaping operations (Ohuchi and Murase, 2004).

In a similar direction are moving also many wood processing factories in Albania. We have seen in the last years in the wood industry in Albania, investments mainly in 3-axis and less in 5-axis machining technology. 5-axis machining provides flexibility and efficiency that cannot be obtained with 3-axis milling, cause a 5-axis machine can produce parts with more complex geometry using a single setup without the need for complex and expensive fixtures. Such machines can produce special geometry, eliminating the use of specialized cutters often used in 3-axis machining (Leondes, 2004).

CNC machinery have a positive impact in terms of lowering costs and the realization of large volumes of work in relatively short time and its continuous utilization with minimal operator involvement. In some cases it is possible to exploit the machine during all the shift, except cases of defects and maintenance interventions (FANUC, 2012).

Realization of large volumes of work in pieces is an important factor in lowering the costs of productions, specially the fix costs, when the wood industry has the necessary large market to sell these quantities of products. Local market for wood products in Albania isn't a large one and this is a factor, which is hindering somehow the extensive use of CNC technology in the country.

In our study case we will analyze two approaches in the production of side elements of the wardrobe in order to achieve higher production time efficiency through using CNC technology. Here we are dealing with vertical drilling operations, horizontal drilling operations and fiber channel sawing. In such cases, drilling programs are better to be created in the machinery editor as it is more practical and focused on demands.

The general physical layout of manufacturing systems of the factory as a major determinant of a firm's efficiency is not taken into account. With the rapidly-changing environment facing most firms today, as well as the shortened life cycles of many products and process technologies, facility rearrangement and redesign become critical in sustaining productivity and competitiveness (Leondes, 2004). Anyway the focus of the paper is more related to time efficiency of single operations.

2. MATERIALS AND METHODS

As already mentioned above in the introduction part the paper is focused in analyzing two approaches in the production of side elements of a wardrobe in order to achieve higher time efficiency through using CNC technology.

After the side elements are worked in the edge banding they are ready to be drilled in the CNC machine, which realizes drilling, milling and fiber channel sawing operations. In this way the assembling of bedrooms can be performed in very short time, not necessarily by two or three people as traditionally done, with qualitative RTA (Ready To assemble) accessories who are quality certified and aesthetic appearance.

Figure 1. *Accessories used in assembling of wardrobes (Hafele, 2012)*

During the study will be taken in consideration time needed for the realization of the drilling process of side elements of a wardrobe. A single side element size is 2400 x 580 x 18 mm and should be drilled for accessories such as Minifix, Rafix, Varianta screws, shelf supports, plastic feets etc. Some of these accessories are presented in Figure 1 above. The dimensions of the side element of the wardrobe and drilling positions are presented in Figure 2.

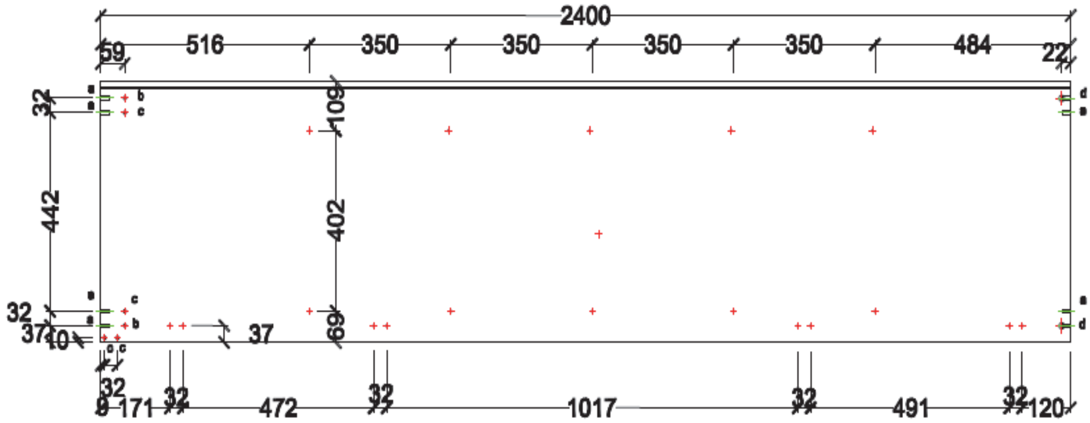


Figure 2. *Dimensions of a side element of the wardrobe*

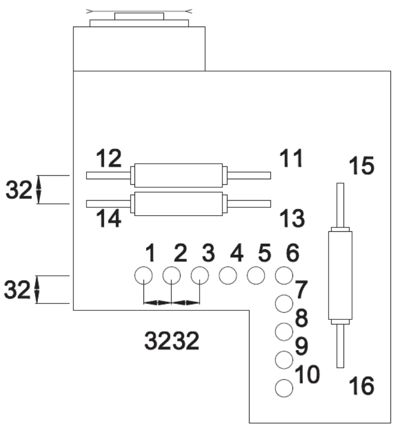
In the Table.1 is presented the list of holes to e drilled and their characteristics, mainly according to their function related to the accessories to be used.

Table 1. *Holes list and their characteristics*

No.	Type	Diameter	Drill depth	No. of holes	Notes
1	a	8	20	8	Horizontal holes
2	b	8	14	2	Holes for metallic sleeves
3	c	8	14	4	Holes for wood dovels
4	d	15	14	2	Holes for metallic connectors
5	e	5	14	18	Holes for Varianta screws and shelf supports

The drilling process is realized with a CNC machinery type Biesse Rover 20, produced in year 2002 and according to Machine User's Manual of NC processing centre Rover 20, with characteristics as below:
Space working of pods and rail table of aluminum elements "easy to position" size 3200x900x100 mm
- Electro spindle power 7 KW
- Equipped with saw aggregate, disc diameter 120 mm, which moves along X axis
- Equipped with drilling group with 10 vertical drilling instruments and 6 horizontal drilling instruments
- Equipped with tool changer with three positions
- Machine control NC 500, with three axis

Drilling group, the saw aggregate and electro spindle are showed in the Figure. 3 below.



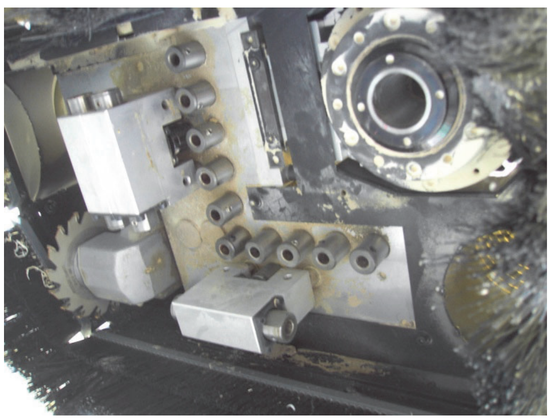


Figure 3. *Graphical representation of drilling (left), drilling group, saw aggregate and electro spindle of the Biesse Rover 20 (right)*

For purposes of the study we configured the drilling group according to the characteristics presented in the Table 2.

Table 2. *Drilling unit initial configuration*

Nr	Diameter	Length	Depth of drilling	Type
1	10	30	15	Counter
2	5	50	40	Normal
3	8	50	40	Normal
4	15	50	40	Normal
5	14	50	40	Normal
6	8	30	20	Counter
7	35	50	40	Large
8	8	50	40	Lance
9	5	50	40	Lance
10	8	50	40	Counter
11	8	50	40	Counter
12	8	50	40	Counter
13	8	50	40	Counter
14	8	50	40	Counter
15	8	30	40	Counter
16	8	30	40	Counter

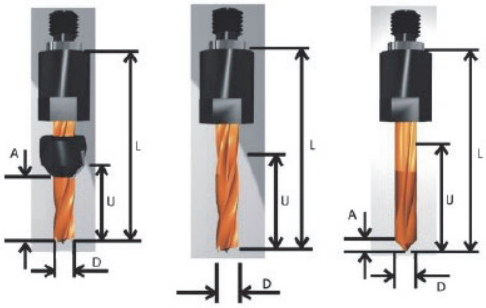


Figure 4. *Different types of drilling tools, counter, lance and normal*

All CNC machine tools require some form of work setting, tool setting, and offsets (compensation) to place the cutter and work in the proper relationship. Compensation allows the programmer to make adjustments for unexpected tooling and setup conditions (Krar and Gill, 1999).

3. RESULTS AND DISCUSSION

Initially we measured the time required for the execution of the program of drilling and fiber channel sawing operation for the side element of the wardrobe, which include measurements related to the time required for the execution of:

- 8 horizontal holes, depth of 20-21 mm and feed rate of 2m/min (changes in depth are made to eliminate simultaneously drilling two a single decrease on Z axis of the drilling group)
- 22 vertical holes, depth of 14-15 mm and feed rate of 3m/min
- fiber channel sawing, feed rate of 4 m/min, in a length of 2.4 m, depth of 9 mm which will be achieved with two steps, because of the consumption of the circular saw

Given the product we want to process with the CNC machinery, we start to write drilling program for the side element of the wardrobe. Thus, as can be seen from the tab.2 above we have to execute vertical and horizontal drilling and fiber channel sawing operations. Horizontal holes are drilled with an advancing speed constant of 2 m/min, vertical holes are drilled with an advancing speed constant by 4 m/min, while the operation of fiber channel sawing is programmed with advancing speed of 4m/min and the number of steps.

Accessories placement is generally standardized and we have to adapt to their requirements. Instruments in the machinery are placed once in machine, are calibrated carefully and with accuracy and their physical configuration must necessarily be reflected in machine control program.

Instruments changes are made in case of damage and instruments repositioning and configuration are advised to be determined according to the drilling unit configuration According to the scheme of assembling required, drilling program and drilling group initial configuration, measurement of time shows that the execution of the program requires about 200 seconds. The time measurement is done once, because the execution time of the program is unchanged. Within this period of 200 seconds about 36% of the time the time spent for disk fiber channel opening.

After executing the necessary operations according the initial configuration of the drilling unit, the drilling scheme is changed and the drilling unit is reconfigured according to the parameters shown in the Table.3.

Table 3. *Recommended drilling unit configuration*

Nr	Diameter	Length	Drilling thickness	Type
1	8	30	20	Counter
2	8	30	20	Counter
3	5	50	40	Lance
4	35	50	40	Large
5	8	50	40	Lance
6	20	50	40	Normal
7	14	50	40	Normal
8	15	50	40	Normal
9	8	30	20	Counter
10	8	30	20	Counter
11	8	50	40	Counter
12	8	50	40	Counter
13	10	50	40	Counter
14	10	50	40	Counter
15	8	50	40	Counter
16	8	50	40	Counter

By measuring the execution time of the program for the changed drilling scheme and a new configuration of drilling unit it turns out that the program execution time takes about 160 seconds. Within this period of 160 seconds, 23% of the time is spent for the fiber channel sawing, because a sharpened cutter blade with diamond-tipped teeth is used.

The result of the study is obvious and can be summed up in the fact that an optimal drilling scheme and a good configuration of machine drilling group influences the use of working time significantly, reducing the time required for the execution of a drilling-sawing program by 25%. A comparison of the time required for the realization of the side component of the wardrobe before and after the improvement of drilling group configuration is shown in the Table.4 below.

Table 4. *Comparison of time before and after improvement of drilling unit configuration*

Time measurement	Needed time (in sec.)		
	Total	Drilling	Sawing
Initial configuration of drilling unit	200	128 (64%)	72 (36%)
Recommended configuration of drilling unit	160	124 (77%)	36 (23%)

We can say that drilling group configuration and calibration of the instruments is a process that requires a lot of time and tests at the beginning of the work, but we achieve a higher precision in work and higher efficiency. A great influence in the time efficiency of the drilling-sawing operation has also the quality of circular saw.

On the other hand the time efficiency increases by the use of CNC machines lies also in the fact that assembly times of the elements are significantly reduced and volumes taken in packing and transportation, affecting at the same time the transport costs.

A greater impact would have the use of a post processor to achieve the transfer of data directly from .dxf CAD formats in the machine language (Ashley, 2003). It would reduce even more the time needed to realize milling operations. Anyway it can be times, as in product replication within a large sheet of material cases, when it can be advantageous to make use of both CAM and manual programming techniques (Overby, 2010).

4. CONCLUSIONS

The use of CNC machines is changing radically the furniture making industry. Time consuming techniques in the production process, such as cutting curves, became much easier. With the advent of wood based panel products such as particle board and medium density fiberboard (MDF), CNC equipment has now been widely adopted for the production of components for many types of furniture.

This study is focused in showing the advantages in time efficiency of the use of CNC equipments in furniture making industry in Albania, specially in the production of furniture parts. We have considered only the drilling-sawing operations on a side element of a wardrobe and measured the program execution times for two drilling schemes and corresponding drilling unit configurations. The optimization of the drilling scheme and especially the drilling unit configuration can increase the time efficiency of the drilling-sawing operation by 25%.

In this paper the efficiency gains in production of "side elements" for wardrobes sized 2400 x 580 x 18 mm are measured only in terms of production time of a single operations, but we have to consider also other several factors influencing the time efficiency as use of appropriate cutting/drilling instruments in order to set high and correct interpolation speeds, use of appropriate post processors, to avoid writing by hand drilling and milling programs, manufacturing large capacities, product standardization, etc.

On the other hand, increasing the time efficiency of production operations through using CNC technology can influence the time efficiency of other operations as assembling, through decreasing it.

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INFULENCE OF KILN SCHEDULE ON DRYING QUALITY OF BEECH WOOD

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ABSTRACT

The defining the final moisture content distribution across thickness of the beech boards during convective kiln drying have been studied. Boards from beech, 50,0 mm thick, 250 -300 mm wide and 1,80 long have been used as testing materials.

The boards have been kiln dried from initial moisture content of 41,93 % to final moisture content of 8,20% for 28 days. In a drying schedule there are four stages: heating, active drying, equalizing and conditioning. It was found that final mean moisture content is 8,20 %.

The moisture content difference i.e. moisture content gradient between core and surface of the boards is 1,68 %.

It was found that by influence of schedule on moisture content distribution it was possible for beech boards to achieve the ,,Q "drying quality according to the European Drying Group.

Key words: Beech, convective drying, drying schedule, moisture content gradient

1. INTRODUCTION

In wood drying technology, there are several different types of wood dryers. As a most representative dryer is the one which work with convective drying method. This dryer is known as classical dryer. For our tests in this paper we have chosen just such a model dryers manufactured by the company BascHild - Italy, with a capacity of 117 m^3.

The work of the dryers is based on the imitation of natural phenomena such as sun, rain and wind in a closed space. In this way in a certain period of time is realized the drying of wood. In these dry kiln phenomenon of the sun is achieved by using heating elements that are heated with hot water. Wind or air movement in achieved by fans, while rain is formed using the device for moistening and change of air. A big advantage of such dryers is that during the drying, temperature and humidity of the air are measured, and thus the control of the wood moisture evaporation is realized.

On the basis of previous stated, the main objective in the overall problem of drying the wood is defining the optimal drying schedule followed by determining the quality of drying.

2. MATERIAL AND METHODS OF WORK

A total quantity of 117 m^3 beech boards was dried for this investigation. Their origin was from central part of Serbia.

The information on the temperature and equilibrium moisture content of the air as content of wood as well as moisture content of wood were obtained with the following probes:

In order to define the drying schedule, the changing of the temperature and equal moisture content (EMC) of the air in the kiln chamber has to be registered as well as the changing of the wood moisture content (MC) during all stages of the drying schedule: stages of heating, active drying, equalizing.

The drying of the beech boards was performed in the convective kiln drier equipped with automatic system of the drying control. (Figure 4)

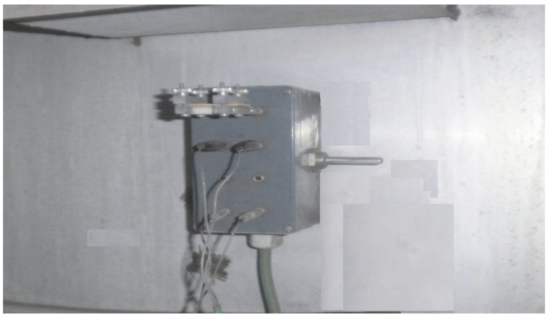

Figure 1. *Measuring of temperature and equilibrium moisture content of air*

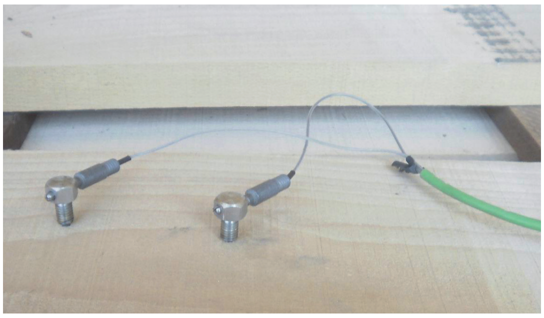

Figure 2. *Measuring of wood moisture content*

Figure 3. *Slicing test (specimen production) for determining of wood moisture gradient across the board's thikness*

Figure 4. *Dry kiln for convective drying*

3. RESULTS AND DISCUSSION

Based on the values of temperature and humidity of the air drying and values for the wood moisture content for 50.0 mm thick beech boards is defined drying schedule shown in Table 1. From the table it can be notice that that the drying schedule starts with the temperature of air of 31,0 ^{0}C, equilibrium moisture content [EMC) of 18,8 % and average moisture content in the wood of 41,9%.

Further the air temperature increased with small oscillations to the value 59,20% of the end of drying schedule (phase of conditioning). The process of evaporation of wood moisture starts with EMC of 18,8% and finish with 4,70%. Average moisture content in the wood measured by four probes reaches its max.value of 41,93%, whereas its minimum value of 10,1 % at the end of the drying schedule. Duration of drying of beech wood is 28 days.

Table 1. *Drying schedule of 50,0 mm thick beech planks*

Time	Phase of drying schedule	Temperature of the air in dry kiln	Equilibrium moisture content	Moisture content Probe Number 1	Moisture content Probe number 2	Moisture content Probe number 3	Moisture content Probe number 4	Average wood moisture content
[day]	F	T [^{0}C]	[%]	[%]	[%]	[%]	[%]	[%]
1	Heating	31,00	18,80	41,5	42,2	46,0	38,0	41,9
2	Heating	29,80	18,80	39,3	39,5	44,0	35,2	39,5
3	Drying	32,00	13,60	37	37	41,7	37,2	38,2
4	Drying	32,00	13,70	35,6	35,8	40,0	32,2	35,9
5	Drying	31,90	13,60	33,7	33,9	38,0	31,1	34,2
6	Drying	27,90	15,10	32,0	32,6	36,1	30,2	32,7
7	Drying	31,90	13,40	31,0	32,0	34,7	29,9	31,9
8	Drying	31,90	13,40	30,0	30,1	32,3	28,1	30,1
9	Drying	31,80	12,20	28,2	29,1	31,1	27,7	29,0
10	Drying	32,00	14,20	27,7	28,5	30,4	27,1	28,4
11	Drying	32,60	13,30	26,8	27,4	29,2	26,0	27,4
12	Drying	35,30	12,50	26,0	26,4	28,4	25,2	26,5
13	Drying	38,30	11,60	25,1	25,3	27,4	24,2	25,5
14	Drying	42,90	10,60	24,4	23,8	26,5	21,3	24,0
15	Drying	36,60	9,70	22,8	21,6	24,7	21,6	22,7
16	Drying	50,40	9,00	22,2	21,3	25,0	21,4	22,5
17	Drying	43,10	10,10	22,3	19,6	24,4	20,6	21,7
18	Drying	59,50	5,90	19,3	17,0	22,2	18,3	19,2
19	Drying	59,30	5,50	17,4	14,5	19,5	15,9	16,8
20	Drying	49,20	6,00	16,8	13,6	17,9	14,6	15,7
21	Drying	59,60	4,90	14,1	13,2	14,8	12,3	13,6
22	Drying	53,60	4,90	13,7	13,0	13,5	12,0	13,1
23	Drying	56,30	5,40	12,3	12,1	12,5	11,8	12,2
24	Drying	57,70	5,40	11,5	11,8	11,5	11,0	11,5
25	Drying	59,80	5,30	11,0	11,2	11,1	10,5	11,0
26	Drying	59,30	5,30	10,5	10,8	10,6	10,4	10,6
27	Equalizing	60,00	4,60	10,1	10,3	10,2	10,2	10,2
28	Conditioni-ng	59,20	4,70	10,0	10,2	10,1	10,2	10,1

Table 2. *Data of surface and core moisture content of beech boards*

Thickness of the wood [mm]	Layer of the wood surface (mark)	Layer of the wood core (mark)	Average moisture content Xsr ± fxs	Standard deviation S ± fs	Coefficient of variation V ± fv
50,0	A		8,60 ± 0,052	0,333 ± 0037	3,871 ± 0,433
	B		8,72 ± 0,047	0299 ± 0033	3,438 ± 0,384
	A+B		8,66 ± 0,036	0,032 ± 0,025	3,694 ± 0,292
		C	10,34 ± 0,048	0,213 ± 0034	2,059 ± 0,325

Based on the data shown in Table 2, it can be concluded that surface moisture content of the board is 8,60 % (layer A) and 8,72 % (layer B), respectively. Average surface moisture content (layers A+B) is 8,66 %. Core moisture content (layer C) of the boards is 10,34 %.

The moisture content gradient which is moisture content differences between the board's core moisture content (MC core) and the board's surface moisture content (MC surface) is 1,68% (Figure 5).

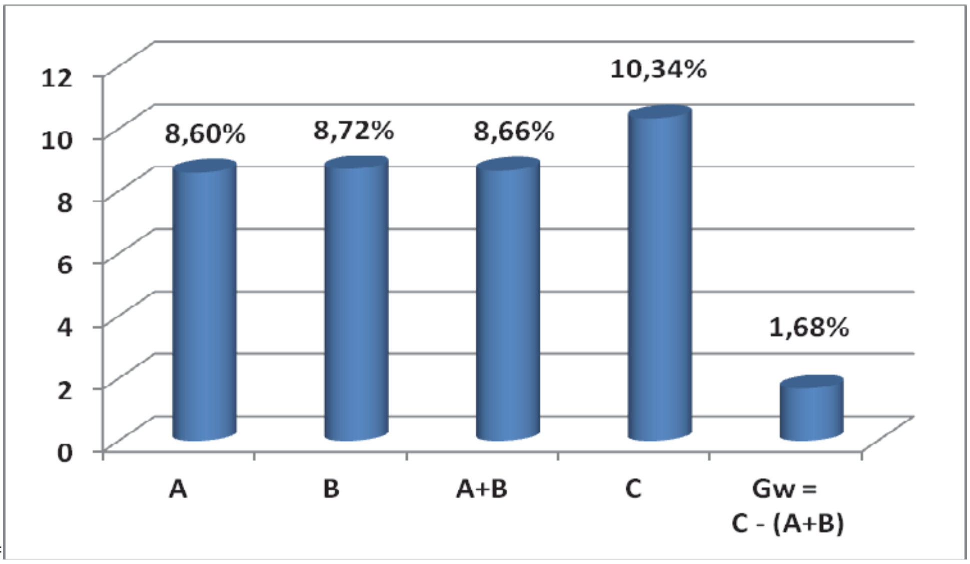

Figure 5. *Wood moisture content distribution (gradient) across the board's thickness*

4. CONCLUSIONS

According to the presented data and results obtained during the drying of beech boards, it can be concluded:

1. The schedule and quality of drying of beech boards has been investigated. There are four phases in the drying schedule: heating, drying, equalizing and conditioning. It was found that the boards were dried dried from their initial average moisture content of 41,9 % to final average moisture content of 10,1 % for 28 days.
2. Temperature of the air increases from 31,0 ^{0}C to around 60 ^{0}C. Equilibrium moisture content decreases from 18,80 % to 4,70 %. Under this drying condition the beech wood losses 31,8 % moisture for 28 days.
3. According to European Drying Group recommendation on assessment of Drying quality of timber the quality of drying corresponds to quality class marked with „Q " (quality dried)
4. The surface moisture content of the boards is 8,66 % (layers A + B)
5. The core moisture content of the boards is 10,34 % (layer C).
6. The moisture content distribution (moisture gradient) across thickness of beech boards during convective drying is 1,68 % that is appropriate for production of products from solid wood.

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CONTROL OF LATERAL DISPLACEMENT OF LOGS BANDSAW

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ABSTRACT

The subject of this paper is rising quality of cutting of bandsaw-logs using signaling devices for correction move, in terms of variability dimensions of raw material, by controlling the trajectory of the cut, when cutting logs of beech.

Due to various reasons (lack of tense saw, too much pressure on the back of the teeth due to excessive speed shift or numbness sawmill) sawmill in the process of cutting can be displaced laterally and as a result it can get assortments of unequal thickness according to their length .

By applying electromagnetic sensor, placed on the upper guide and light signaling the worker can promptly react by reducing the speed of the displacement, so that the lateral displacement of the saw is smaller limits.

Variability obesity of raw material using this signaling device has twice smaller values in relation to the variability of the thickness without using the device.

Values of t-test showed very high and expressed significance (difference) between corresponding pairs of comparison; t-test shows that the use of signaling devices appears a significant positive difference.

Key words: woodworking, bandsaw, displacement, thickness variability, electromagnetic sensor

1. INTRODUCTION

In the process of sawing the logs with bandsaw, the high cutting speed causes lateral displacement of the blade. This is due to increased pressure on the back side of teeth. Cutting tool and sawing trajectory are not parallel.

This phenomenon results in board thickness variability for a certain length of assortments.

Therefore, it is important to choose a cart velocity to be close to the speed limit while lateral displacement of the blade to be within permited limits.

2. AIM

The purpose of this research is to control the lateral displacement of bandsaw using electromagnetic sensor and signal conditioning.

3. PAST RESEARCH

More authors lateral displacement of the blade associated with vibration of the saw and the increased pressure on the back side of the teeth.

Optimal control of vibration expressed through lateral displacement of the blade requires fundamental knowledge and influencing the dynamic characteristics of cutting. The dynamic link is established between cutting tool and body of the saw-Mote CD (1975).

Ulsou A.G., Mote C.D., Szumani R. (1978) note that the lateral stability of cutting tool-bandsaw depends on several parameters, such as axial tension of the saw, the free distance between the guide and the stump, type of guides, the components of the cutting force (normal, tangential and transverse), thickness and width of the blade, resulting lateral forces created by the auxiliary blade teeth with interreaction, the positioning of the wheels and their eccentric and a very important preparation for the blade work.

Sugihara H. (1953) Dynamic sawing highlights is major impact on the stability and vibration of the saw, and it is very important for the scientific investigation of the relationship between vibration and forces sawing, relationship-speed, power consumption, precision sawing, etc.. The author experimentally proved that the normal force of sawing grows linearly with the speed of the shift.

Breznjak M. and Moen K. (1972) in their research found that the increase in vibration and lateral displacement of cutting tools for sawing, increasing loss of timber and energy consumption (that is roughly proportional to the magnitude of vibration). Also, it has vibration and lateral displacement of the blade increases with increasing distance between the guide and the site of penetration of the teeth into the wood and the speed of displacement of the processed item.

Trposki Z. (1992, 1993, 1996), when examining cutting in beech and pine concluded that the vibration of the blade and thus lateral stability grows proportionally with the increase of: moving the cart at a constant height of sawing and active time, the height of sawing, at constant feed and actively working hours active time, at a constant level of feed and sawing. Control the vibration of the saw are easily accomplished by choosing the optimum feed. The speed of moving the cart is a important factor that directly determines the components of the mode of sawing. Imbalance of pressure forces and friction on the front of the teeth and the forces of pressure and friction on the back side of the teeth leads to the displacement of the trajectory of the teeth. It leads to the anparalleled of saw with intended cutt area. Trposki Z, concluded that the increase in the feed cart leads to increased vibration and its lateral displacement values from 125 to 1900μm.

Klincarov R. (1978) investigated the influence of vibration in bandsaws depending on the height and thickness of sawing boards and how it is manifested on the cutting surface. It concluded that: the blade vibration and lateral displacement is directly proportional depending on the height of sawing, while getting worse quality of cutting surface, the vibration of the blade depends on the thickness of the boards inversely; sawing quality expressed through absorption of the surface depends on straight cutting height of sawing and inversely proportional to the thickness of the boards. The uncontrolled increase of the cart moved often causes extreme variability of the thickness up to 4mm.

4. OBJECT AND METHOD OF RESEARCH

Factory: "Suvo Laki"-Berovo
Machine: bandsaw "BRATSTVO"-1100mm

Logs are originating from the locality "Klepalo" Mountain Ogražden the same location of growth, second-class quality, length of 4,0 m and diameter 33,0 to 35,0 cm.

To obtain more accurate results of measurements that can be compared with high precision we are select 10 logs nearly equal diameter and features. Grouped into two groups of 5 logs. The first group of five logs are cutted without using a sensor and alarm light, and the second group of five logs are cutted using electromagnetic sensor and signal light in production conditions. First are processed first log from the first group and then first log of the second group, following a second log of the second group and then the second from the first trunk group, etc. (Figure 1). In this way largely avoided the impact of zatapuvanjeto teeth.

The basics of sawing logs at all identical and received the same heights of sawing logs at all in logs of the number of incision and different in terms of incisions only one log (Figure 2).

It is important to note that will analyze and compare only identical heights of sawing to cut concrete and well-defined set of logs (eg first log, first section, without signaling, in relation to the first log, first section, signaling).

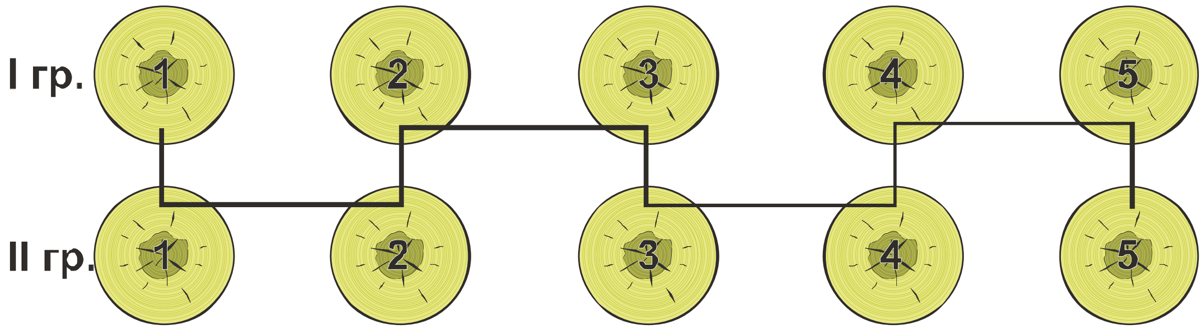


Figure 1. *Order of sawing logs*

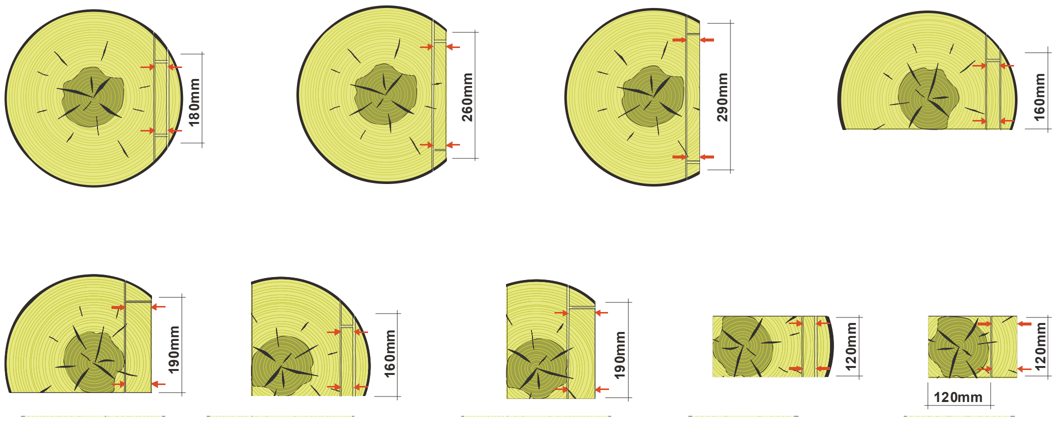


Figure 2. *Order to perform incisions with stumps*

The method of measurement of the thickness deviation (variability) is shown in the Figure 3.

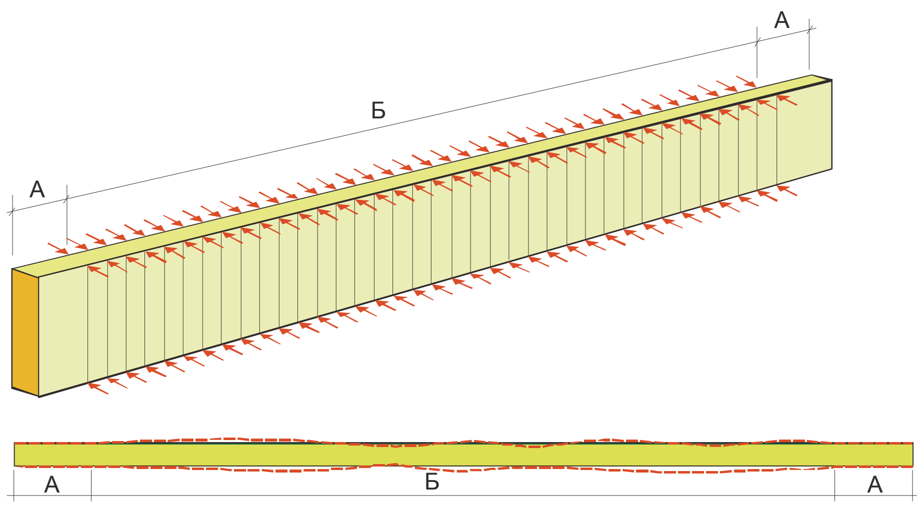


Figure 3. *Measurements of the thickness deviation: A thick zone of reference, B-zone measurements of deviations*

When sawing logs as electromagnetic sensor light signaling instrument is used JOERG KG type A-Z0 manufactured in Germany (Figure 4). Instrument by measuring scale (5) measures the deviation from the normal trajectory of the blade, to + /-1mm. Signal lights gradually come on when the deviation reaches the value of 0,3 mm and gradually go off when the saw is back. Lights are on and off gradually in order to protect workers from sudden reactions. In this way the employee is correct and timely informed about the condition of the saw at all times.

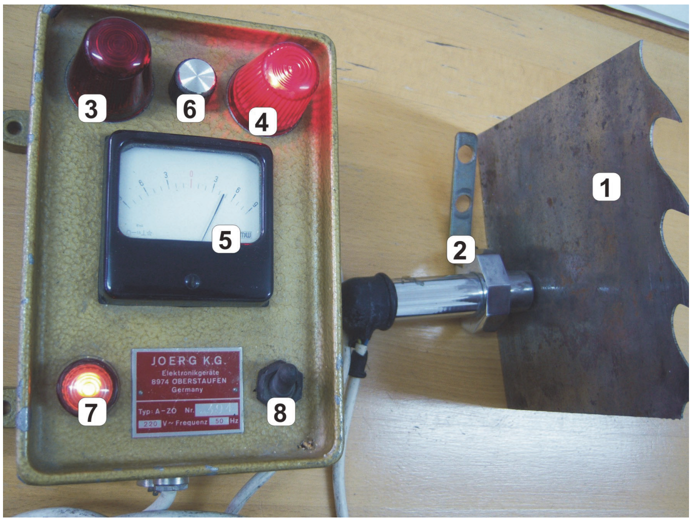


Figure 4. *Electromagnetic sensor light signaling device*
1-bandsaw, electromagnetic sensor 2, 3, 4-lamps for signaling that the saw moves left or right, 5-tool for measuring the size of the displacement (in 0,1 mm), 6-potentiometer for adjusting the measurement scale, 7-involvement indicator device, 8-Switch

Electromagnetic sensor light signaling instrument is used JOERG KG type A-Z0 manufactured in Germany (Figure 4). Instrument by measuring scale (5) measures the deviation from the normal trajectory of the blade, to + /-1mm. Signal lights gradually come on when the deviation reaches the value of 0,3 mm and gradually go off when the saw is back. Lights are on and off gradually in order to protect workers from sudden reactions. In this way the employee is correct and timely informed about the condition of the saw at all times.

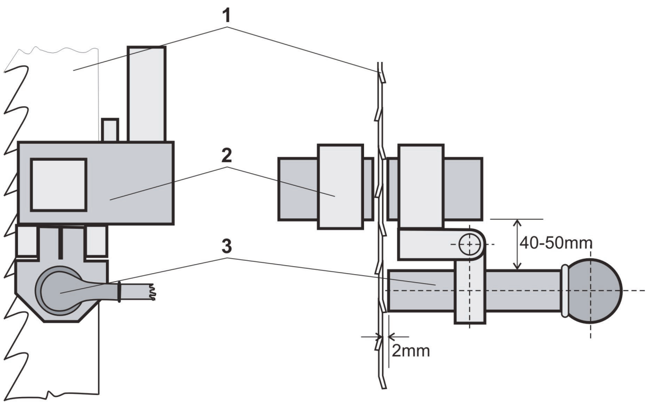


Figure 5. *Placement of electromagnetic sensor in terms of blade*
1-bandsaw, 2-upper bracket, 3-electromagnetic sensor

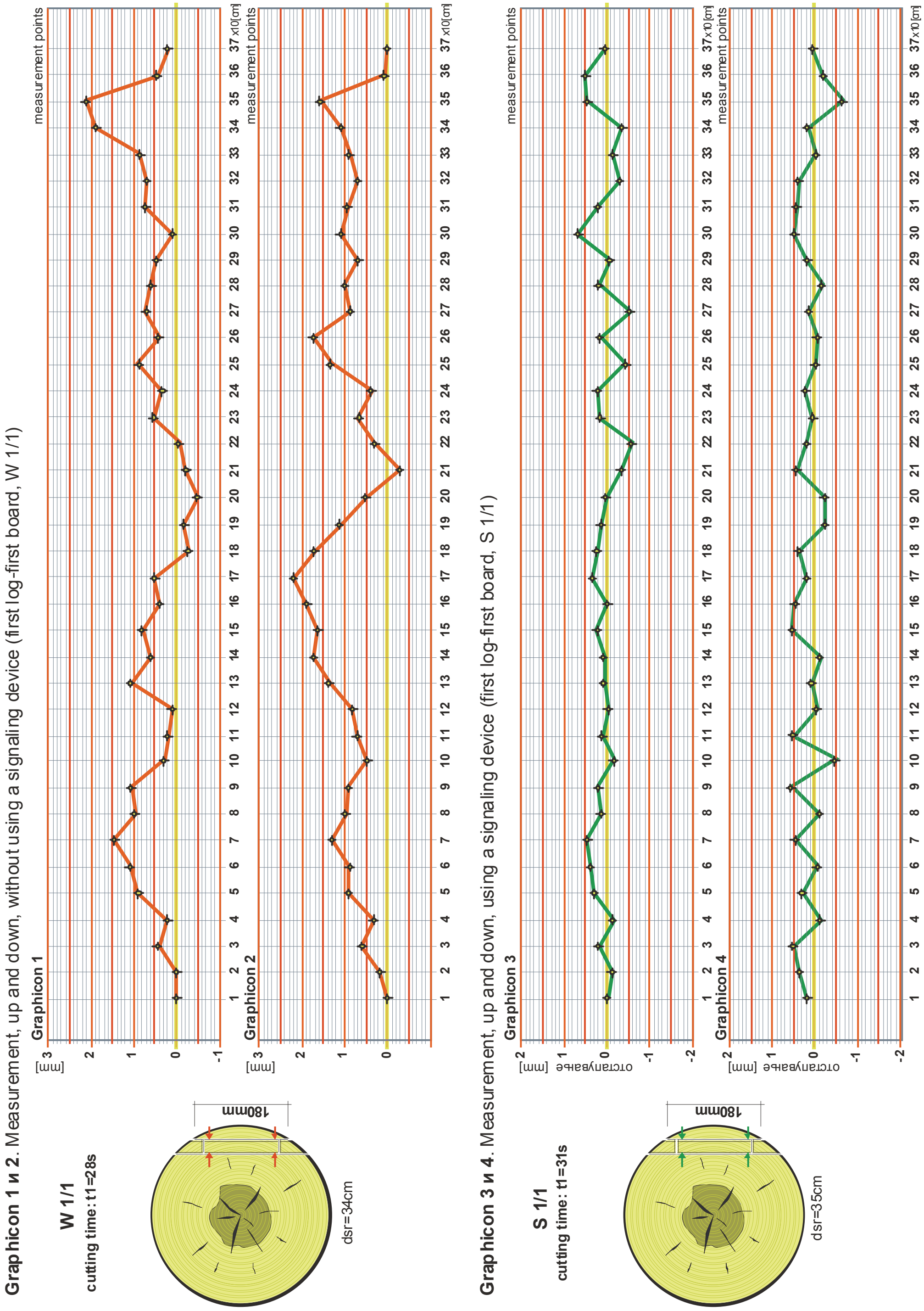
5. RESULTS AND DISCUSION

The obtained measurements are presented in 15 tables and 180 charts.

Due to the sheer volume of work, and because of the similarity of statistical indicators will only show the first analysis stump.

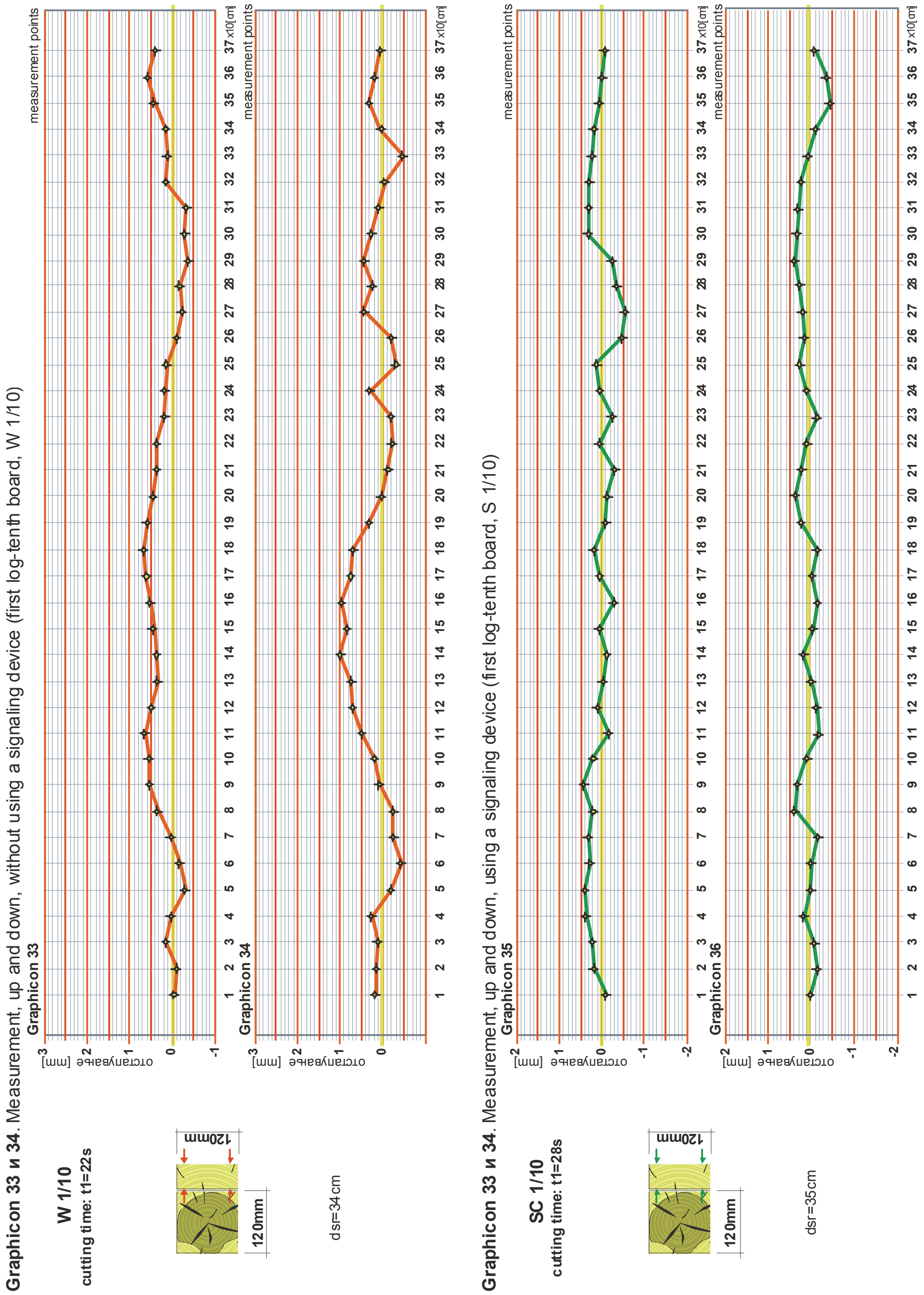
Statistical processing of the measurements for the first three planks of the first logs of both groups show that all statistical indicators for measurements without using signaling is almost three times higher values, ie mean, 0,60 mm <B xsr <0,88 mm, a 0, 24mm <C xsr <0,34 mm. The standard error of measurement in Sx measurements without signaling (first group) ranges from 0,09 to 0,12 mm while the measurements of signal (second group) from 0,03 to 0,04 mm and about three times larger.

Maximum on the first group is 2,80 mm and the second 0,85 mm, which is more than three times. The standard deviation SD in the first group ranges from 0,49 to 0,72 mm and the second from 0.17 to 0,22 mm. The coefficient of variation of measurements in both groups, the first three cuts show pronounced inhomogeneity, ie the first group ranges from 63.24 to 92.84%, while the second from 59.56 to 70.58%. Values of coefficient of variation in addition to the second group. The values of t-test showed high expression and significance (difference) between corresponding pairs of comparison. For better understanding of the nature of these measurements are shown graphically. Easy to see that the values of the measurements for the first group (red line) are greater than the values for measurements from the second group (green line).



Graphicon 1 и 2. Measurement, up and down, without using a signaling device (first log-first board, W 1/1)

Graphicon 3 и 4. Measurement, up and down, using a signaling device (first log-first board, S 1/1)



Graphicon 33 и 34. Measurement, up and down, without using a signaling device (first log-tenth board, W 1/10)

Graphicon 33 и 34. Measurement, up and down, using a signaling device (first log-tenth board, S 1/10)

It is important to pay attention to the required active during sawing for each section separately and the total of all cuts according to the cutting logs groups with and without signaling device. Active time required for each section are shown in Table 1.

For us it is particularly interesting the total time of the five sawing logs without using and five logs using a signaling device. As can be seen the difference between them is only 128 s in favor of the group without using signaling device. Certainly timely correction of moving cart creates a small loss of time. Time is lost in favor of assortments quality. On the other hand, stress the blade and therefore the moving parts of the machine are reduced. In extreme strain saw her bending over can lead to its breakage.

***Table 1**. Active during the sawing of each section and total time of sawing logs from the appropriate group*

No of log	W/S signalling	Number of cutting									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	Total
I	**W**	28	39	44	27	33	30	35	26	22	**284**
	S	31	45	39	32	39	35	33	29	28	**311**
II	**W**	27	44	45	36	39	34	37	26	33	**321**
	S	31	39	48	37	36	41	44	32	35	**343**
III	**W**	78	45	92	74	110	35	87	38	33	**592**
	S	61	47	98	67	101	40	93	42	35	**584**
IV	**W**	33	34	49	30	40	36	37	18	19	**296**
	S	34	44	55	38	41	41	40	22	26	**341**
V	**W**	31	39	42	29	30	30	37	18	23	**279**
	S	34	47	40	30	36	41	43	27	23	**321**
Total: **W = 1772s** Total **S = 1900s Difference = 128s**											

6. CONCLUSIONS

The results of the analysis will carry out separately for each group of logs processed as a group conclusions and then bring them common.

First Conclusions for processing the first log of the first group (without signaling) and first log in the second group (with signs).

- the mean of the measurements is from 0,31 mm to 0,88 mm, while the mean of the measurements of the second group is from 0,18 mm to 0,39 mm,
- standard error in the measurements of the first group ranges from 0,03 to 0,12 mm for measurements while the second group from 0,02 to 0,05 mm,
- maximum values in the first group is 2,80 mm and the second 1,15 mm,
- standard deviation for the first group is in the range of 0,19 to 0,72 mm and the second from 0.13 to 0,31 mm,
- coefficient of variation of measurements in both groups show pronounced inhomogeneity, ie the first group ranges from 60.22 to 92.84%, while the second from 57.80 to 80.86%
- the values of the t-test also showed high expression and significance (difference) between corresponding pairs of comparison.

Second Conclusions for processing the second log from the first group (without signaling) and second log of the second group (with signs).

- the mean of the measurements in the first group is from 0,33 mm to 0,57 mm, while the mean of the measurements in the second group is from 0,17 mm to 0,39 mm,
- standard error in the measurements of the first group ranges from 0,04 to 0,06 mm for measurements while the second group from 0,02 to 0,05 mm.
- maximum values in the first group is 1,30 mm and the second 1,10 mm,
- the standard deviation in the first group ranges from 0,23 to 0,35 mm and the second from 0.12 to 0,25 mm,
- coefficient of variation of measurements in both groups show pronounced inhomogeneity, ie the first group ranges from 60.37 to 85.19%, while the second from 60.73 to 86.94%
- values of t-test showed high expression significance (difference) between corresponding pairs of comparisons, and only in two cases comparing pairs no significant difference.

3rd Conclusions for processing third log from the first group (without signaling) and third log of the second group (with signs).

- the mean of the measurements in the first group is from 0,32 mm to 0,71 mm, while the mean of the measurements in the second group is from 0,21 mm to 0,34 mm,
- standard error of the mean, the first group ranges from 0,04 to 0,09 mm for measurements while the second group from 0,02 to 0,04 mm,

• maximum values in the first group (measurements without signaling device) was 2,10 mm and the second (a signaling device) was 1,05 mm,
• the standard deviation in the first group measurements, ranges from 0.27 to 0,52 mm and the second set of measurements from 0.15 to 0,24 mm,
• coefficient of variation of measurements in both groups, collectively for all cuts shows pronounced inhomogeneity, ie the first group ranges from 65.81 to 88.89%, while the second group of measurements from 62.22 to 84.31%
• values of t-test showed high expression and significance (difference) between corresponding pairs of comparisons, and only one case of comparing pairs no significant difference.

4th Conclusions for processing the fourth log in the first group (without signaling) and fourth log of the second group (with signs).
• the mean of the measurements in the first group is from 0,29 mm to 1,00 mm, while the mean of the measurements of signal (second group) is from 0,20 mm to 0,34 mm,
• standard error of the mean, the first group ranges from 0,04 to 0,12 mm while the second group from 0,02 to 0,04 mm,
• the maximum value in the first group was 2,35 mm while the second is 1,00 mm,
• Standard deviation in measurements first group ranges from 0,24 to 0,72 mm and the second set of measurements from 0,11 to 0,22 mm,
• coefficient of variation of measurements in both groups, showing more pronounced inhomogeneity, ie the first group ranges from 64.06 to 95.90%, while the second group of measurements from 55.86 to 80.72%
• values of t-test showed very high expression and significance (difference) between corresponding pairs of comparison,

5th Conclusions for processing the fifth log from the first group (without signaling) and fifth log of the second group (with signs).
• the mean of the measurements in the first group is from 0,30 mm to 0,51 mm, while the mean of the measurements in the second group is from 0,16 mm to 0,29 mm,
• standard error of measurement, the first group ranges from 0,04 to 0,05 mm for measurements while the second group from 0,02 to 0,04 mm,
• maximum values in the first group (measurements without signaling device) was 1,45 mm and the second (a signaling device) was 0,85 mm,
• the standard deviation in the first group measurements, ranges from 0.22 to 0,39 mm and the second set of measurements from 0,13 to 0,22 mm,
• coefficient of variation of measurements in both groups, showing more pronounced inhomogeneity, ie the first group ranges from 61.05 to 85.95%, while the second group of measurements from 61.38 to 89.57%
• values of t-test showed very high expression and significance (difference) between corresponding pairs of comparison.

Common findings on the processing of logs from the first (without signaling) and the second group (with signs).
• the mean of the measurements in the first group is from 0,29 mm to 1,00 mm, while the mean of the measurements in the second group is from 0,16 mm to 0,34 mm; latter group, ie the measurement signal having more than two times smaller values ,
• standard error of measurement in the first group ranges from 0,04 to 0,12 mm for measurements while the second group from 0,02 to 0,05 mm; latter group is twice smaller values
• maximum values in the first group (measurements without signaling device) was 2,80 mm and the second (a signaling device) is 1,15 mm; more than two times lower values in the second group,
• the standard deviation in the first group measurements, ranges from 0.19 to 0,72 mm and the second set of measurements from 0,11 to 0,31 mm; twice smaller values for the second group,
• coefficient of variation of measurements in both groups, showing more pronounced inhomogeneity, ie the first group ranges from 60.37 to 95.90%, while the second group of measurements from 55.86 to 89.57%, due to higher inhomogeneity of data, the coefficient of variation is unmatched, but the second group shows better homogeneity,

• values of t-test showed very high expression and significance (difference) between corresponding pairs of comparison; t-test shows that the use of signaling devices appears significant positive difference.
• total active during the sawing of logs from the first group (without signaling) and the second group (the signal) is different for 128 s, in favor of the first group, the time difference is negligible in relation to the quality of the resulting variability of obesity.

Overall, the results show that the use of light-signaling devices for sawing with logs bandsaw in order correction to move the cart is justified and important in terms of quantity and quality of raw material utilization.

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THE INFLUENCE OF EXTRACTIVES IN BENDING AND COMPRESSION STRENGTH OF BLACK PINE (*Pinus nigra* Arn.)

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ABSTRACT

The study regards on mechanical properties of black pine (*Pinus nigra* Arn.), and especially in the effect of extractives content in static bending strength and in compression strength. The study is carried out at the Laboratory of Wood Technology in Forest Science Faculty. 160 samples from sapwood and heartwood are prepared from timber piles. Half of samples are extracted in organic extractives first and then in hot water 60 ºC. All samples are air dried in 12% humidity. The tests of static bending strength and compression strength are done according the standard UNI-ISO 31-33. The results showed that the mean values for compression strength was 43 N/mm^2, and the mean value for bending strength was 89 N/mm^2. Because of extracting: the bending strength is reduced about 13 % for heartwood and 6% for sapwood.

Key words: black pine, extractives, bending strength, compression strength

1. INTRODUCTION

Black pine (*Pinus nigra* Arn.), is not only wide spread species in Albanian forests but also this used material in wood industry and different industries (e.g. furniture, timber, plywood, out-door applications). For optimal utilization of these specie by industry the chemical, anatomical and mechanical properties have to be well known. Among these properties, only the mechanical specifications are frequently considered by the industry. It is known, that the chemical composition of wood has an influence on the physical and mechanical properties. In the cell wall, for example, low molecular weight substances occupy the same space in which hygroscopic water could enter. Due to this, extractives lower the equilibrium moisture content (EMC) of wood and reduce swelling and shrinking, Ekman R, et al (1989) and Fengel et al (2003). A linear correlation between the extractive content and EMC at fiber saturation point (FSP) was confirmed by Popper et al (2007). FSP is affected by the presence of extractives and increased after the removal of wood extractives Hillis, W.E. (1971). Extractives had little effect on the monolayer sorption of water but an appreciable effect on the poly layer sorption. Choong et al (1991) indicated that removing extractives with hot water and organic solvents causes excessive shrinkage in tropical woods. In various studies, the importance of extractives on the physical and mechanical properties of wood species have been emphasized. Although, there are some studies on physical and mechanical properties of some european and tropical woods, very limited data were obtained for effect of extractives on mechanical properties.

2. MATERIAL AND METHOD

The study involve black pine (*Pinus nigra* Arn.),, as the representative of softwoods. The aim of the study is to compare the bending and compression strength of extracted samples with the unextracted ones. There is cut one log. 160 samples were obtained from quartersawn boards (80 samples from sapwood and 80 from heartwood). Samples have the dimension 2x2x32 cm for bending strength test and 2x2x4 cm for compression strength. Half of samples are extracted. The extracted solvent is prepared as the mixer of toluene with ethanol (1:1). This solvent has a very deep extraction effect, Nelson L. et al. (2004) and it is the best substitute of benzene (a solvent with hazard effect on human health). The samples are soaked in solvent for 15 days, changing the solvent every two days followed by ten days water extraction at 60 °C, both durations sufficient to remove all relevant extracts Mantanis et al (1995). All the samples were air dried until they reached 12 % moisture content. After that, the mechanical test are done.

3. RESULTS

Bending

After collecting the values of the forces in breaking F by the material tests machinery, the tension in bending was calculated with the formula:

$$\partial = \frac{3}{2}\frac{Fl}{bh^2} \quad N/mm^2$$

Where:

F - force in breaking (N)
l- sample length (mm)
b- transversal section width (mm)
h- transversal section height (mm)

Unextracted samples						**Extracted samples**					
Nr	**Sapwood**		**Nr**	**Heartwood**		**Nr**	**Sapwood**		**Nr**	**Heartwood**	
	Force (N)	Sigma (N/mm^2)		Force (N)	Sigma (N/mm^2)		Force (N)	Sigma (N/mm^2)		Force (N)	Sigma (N/mm^2)
1	2001	105.1	1	2201	115.6	1	1923	101.0	1	1968	103.3
2	1988	104.4	2	2187	114.8	2	1926	101.1	2	1950	102.4
3	2081	109.3	3	2289	120.2	3	1925	101.1	3	1970	103.4
4	2176	114.2	4	2393	125.7	4	1923	101.0	4	1968	103.3
5	1990	104.5	5	2189	114.9	5	1923	101.0	5	1954	102.6
6	2003	105.2	6	2203	115.7	6	1923	101.0	6	1951	102.4
7	1995	104.7	7	2195	115.2	7	1926	101.1	7	1976	103.7
8	2231	117.1	8	2454	128.8	8	1925	101.1	8	1956	102.7
9	2130	111.8	9	2343	123.0	9	1924	101.0	9	1954	102.6
10	1990	104.5	10	2189	114.9	10	1924	101.0	10	1962	103.0
11	1994	104.7	11	2193	115.2	11	1922	100.9	11	1954	102.6
12	2004	105.2	12	2204	115.7	12	1916	100.6	12	1958	102.8
13	2100	110.3	13	2310	121.3	13	1925	101.1	13	1957	102.7
14	2000	105.0	14	2200	115.5	14	1920	100.8	14	1970	103.4
15	1989	104.4	15	2188	114.9	15	1921	100.9	15	1969	103.4
16	1990	104.5	16	2189	114.9	16	1923	101.0	16	1953	102.5
17	1994	104.7	17	2193	115.2	17	1922	100.9	17	1951	102.4
18	1997	104.8	18	2197	115.3	18	1922	100.9	18	1945	102.1
19	1999	104.9	19	2199	115.4	19	1923	101.0	19	1956	102.7
20	1985	104.2	20	2184	114.6	20	1925	101.1	20	1948	102.3
21	1890	99.2	21	2079	109.1	21	1919	100.7	21	1964	103.1
22	1995	104.7	22	2195	115.2	22	1926	101.1	22	1975	103.7
23	2001	105.1	23	2201	115.6	23	1935	101.6	23	1959	102.8
24	2002	105.1	24	2202	115.6	24	1931	101.4	24	1956	102.7
25	1995	104.7	25	2195	115.2	25	1932	101.4	25	1965	103.2
26	2000	105.0	26	2200	115.5	26	1933	101.5	26	1973	103.6
27	2000	105.0	27	2200	115.5	27	1934	101.5	27	1966	103.2
28	2002	105.1	28	2202	115.6	28	1929	101.3	28	1982	104.1
29	2002	105.1	29	2202	115.6	29	1931	101.4	29	1983	104.1
30	1989	104.4	30	2188	114.9	30	1933	101.5	30	1969	103.4
31	1995	104.7	31	2195	115.2	31	1928	101.2	31	1967	103.3

32	1989	104.4	32	2188	114.9	32	1929	101.3	32	1979	103.9
33	1999	104.9	33	2199	115.4	33	1925	101.1	33	1971	103.5
34	1999	104.9	34	2199	115.4	34	1926	101.1	34	1977	103.8
35	1995	104.7	35	2195	115.2	35	1928	101.2	35	1975	103.7
36	1995	104.7	36	2195	115.2	36	1925	101.1	36	1966	103.2
37	1999	104.9	37	2199	115.4	37	1925	101.1	37	1975	103.7
38	1998	104.9	38	2198	115.4	38	1922	100.9	38	1959	102.8
39	1999	104.9	39	2199	115.4	39	1922	100.9	39	1950	102.4
40	2005	105.3	40	2206	115.8	40	1922	100.9	40	1952	102.5
Average		**108.1**	**Average**		**118.2**	**Average**		**101.2**	**Average**		**103.1**
STDV		**2.9**	**STDV**		**3.2**	**STDV**		**0.2**	**STDV**		**0.5**

Compression

After collecting the values of the forces in breaking F by the material tests machinery, the tension in compression was calculated with the formula:

$$\sigma = \frac{F}{S} \quad (\text{N/mm}^2)$$

Where:

F - force in breaking (N)

S- transversal section (mm^2)

Unextracted samples						**Extracted samples**					
Nr	**Sapwood**		**Nr**	**Heartwood**		**Nr**	**Sapwood**		**Nr**	**Heartwood**	
	Force (N)	Resistance σ N/mm²		Force (N)	Resistance σ N/mm²		Force (N)	Resistance σ N/mm²		Force (N)	Resistance σ N/mm²
1	18912	47.3	1	23593	59.0	1	17653	44.1	1	24975	62.4
2	18997	47.5	2	22931	57.3	2	17842	44.6	2	22837	57.1
3	18349	45.9	3	24407	61.0	3	17615	44.0	3	20055	50.1
4	19015	47.5	4	24390	61.0	4	17539	43.8	4	21090	52.7
5	17709	44.3	5	22389	56.0	5	17577	43.9	5	24161	60.4
6	18277	45.7	6	23987	60.0	6	17842	44.6	6	22996	57.5
7	19545	48.9	7	24687	61.7	7	17671	44.2	7	20604	51.5
8	17990	45.0	8	24556	61.4	8	18220	45.6	8	25921	64.8
9	17989	45.0	9	22789	57.0	9	17369	43.4	9	23593	59.0
10	17989	45.0	10	23518	58.8	10	18050	45.1	10	20718	51.8
11	19072	47.7	11	24199	60.5	11	17567	43.9	11	21815	54.5
12	18893	47.2	12	24345	60.9	12	17601	44.0	12	25183	63.0
13	19242	48.1	13	23987	60.0	13	17587	44.0	13	26148	65.4
14	18568	46.4	14	23385	58.5	14	17546	43.9	14	20510	51.3
15	18769	46.9	15	24345	60.9	15	17678	44.2	15	24842	62.1
16	17892	44.7	16	22439	56.1	16	17677	44.2	16	22439	56.1
17	18034	45.1	17	24378	60.9	17	17685	44.2	17	21454	53.6
18	18760	46.9	18	24341	60.9	18	17800	44.5	18	21569	53.9
19	18670	46.7	19	24142	60.4	19	17651	44.1	19	21711	54.3
20	18562	46.4	20	26053	65.1	20	17538	43.8	20	21437	53.6
21	17989	45.0	21	25221	63.1	21	17612	44.0	21	20680	51.7
22	18244	45.6	22	23139	57.8	22	17345	43.4	22	22458	56.1
23	17789	44.5	23	24343	60.9	23	17364	43.4	23	19901	49.8
24	18031	45.1	24	22879	57.2	24	17342	43.4	24	18409	46.0
25	17988	45.0	25	24761	61.9	25	17655	44.1	25	19821	49.6
26	17893	44.7	26	23158	57.9	26	17899	44.7	26	19807	49.5
27	18672	46.7	27	25240	63.1	27	17612	44.0	27	19299	48.2
28	18565	46.4	28	24892	62.2	28	17666	44.2	28	18996	47.5
29	18267	45.7	29	24538	61.3	29	17401	43.5	29	19242	48.1

30	18349	45.9	30	24189	60.5	30	17101	42.8	30	19923	49.8
31	18324	45.8	31	23990	60.0	31	17343	43.4	31	19921	49.8
32	18034	45.1	32	24012	60.0	32	17234	43.1	32	19899	49.7
33	18200	45.5	33	24238	60.6	33	17321	43.3	33	19967	49.9
34	18299	45.7	34	23987	60.0	34	17234	43.1	34	21034	52.6
35	17998	45.0	35	23509	58.8	35	17242	43.1	35	20954	52.4
36	18821	47.1	36	23546	58.9	36	17111	42.8	36	22045	55.1
37	17890	44.7	37	23433	58.6	37	17201	43.0	37	23012	57.5
38	17987	45.0	38	23657	59.1	38	17211	43.0	38	23231	58.1
39	18543	46.4	39	23770	59.4	39	17167	42.9	39	21980	55.0
40	18345	45.9	40	23878	59.7	40	17232	43.1	40	22341	55.9
Average		**46**	**Average**		**60**	**Average**		**43.8**	**Average**		**54**
STDV		**1.1**	**STDV**		**1.9**	**STDV**		**0.6**	**STDV**		**2.2**

4. CONCLUSION

According the calculation resulted that:

Bending strength is decreasing about 13% for heart wood and 6 % for sapwood in extracted samples.

Compression strength is decreasing about 10 % for heart wood and 5 % for sapwood in extracted samples.

This results show that the presence of extractives in wood effects in better mechanical resistance properties. Especially, the higher content of extractive in heartwood leads to a better mechanical resistance of this part of wood in comparison with sapwood.

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EXPERIMENTAL AND SIMULATED SAWING OF WHITE PINE LOGS

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ABSTRACT

Subject of this paper is analysis of max quantitative exploitation when treating experimentally (in practice) white pine logs and simulating treatment applying computer supported programme. The major goal is, by means of experimental tests and simulation of treatment of the logs, to obtain information on max quantitative exploitation. Study objects are white pine logs. They are 4 m. long, with quality class I/П, with diameter ranging between 25,0 and 75,0 cm, distributed in V (five) thickness classes.

Technologically, the logs were first sawn on logs bandsaw, and the secondary treatment involved longitudinal and transversal sawing. The treatment applied was the so called "purposeful" sawing, which enabled obtaining specimens for construction purposes. Max quantitative exploitation from experimental tests ranges between 66,82% and 76,43%, the mean value being 71,86%. When simulating the sawing process, the values are higher and range between 68,83% and 78,00%, the mean value being 74,42%. For simulation of the treatment process, a programme entitled "simulation-SBG" was prepared.

1. INTRODUCTION

Due to the fact that in the sawmills exact analyses based on experimental sawing or on applying programmes for computer simulation are not frequently applied, quite often unreliable data is used for quantitative exploitation. Based on these facts, this paper describes how experiments and simulation programme were used to study max quantitative exploitation when treating white pine logs, throughout all the treatment stages.

2. WORKING METHOD

For realization of the goals set, we opted for the company 'DRVO BOR", where 80,00% of the total logs are white pine logs, 15,0 % are black pine and 5,0% are beech logs. With the purpose of providing for smooth running of the technological process, the sawmill was fitted with a logs bandsaw and machines for secondary treatment.

Regarding the working methodology applied, in this paper we cover a few stages related to the raw material, sawing dispositions, applied methods for data processing and simulation of the programme. Depending on their mean diameter, the logs were distributed into the following classes: from 25,0 to 35,0 cm., from 35,1 – 45,0 cm., from 45,1 to 55,0 cm., from 55,1 to 65,0 cm. and from 65,1 to 75,0 cm.

Depending on the diametre of the logs, by experiment, and with the purpose of obtaining max quantitative exploitation, a suitable sawing disposition was applied. Figures 1 and 2 show the way of sawing logs with diameter from 36,0 to 45,0 cm. and from 56,0 to 65,0 cm.

Figure 1. *Sawing disposition*
d = 35,1 – 45,0 cm.)

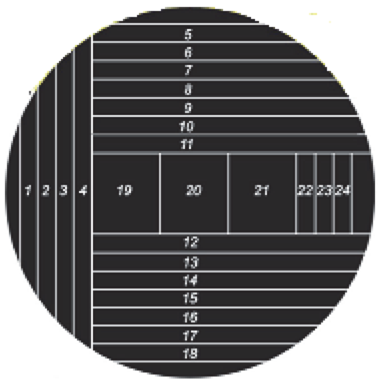


Figure 2. *Sawing disposition*
(d = 55,1 – 65,0 cm.)

In order to calculate the volume of the logs and the samples, the dimensions are taken applying mathematical formulas and methods from variation statistics.

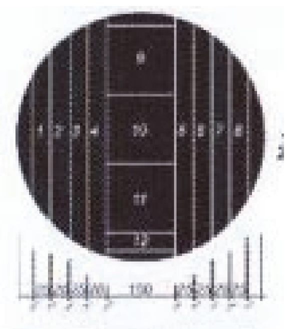
When preparing the simulation programme referred to as “simulation-SBG”, we used input values, output values and invariable values.

The programme “simulation-SBG” was prepared to simulate sawing white pine logs, using so called sharp sawing, shaping prism and prism sawing. This is a way to reach quickly and simply data regarding quantitative exploitation, as well as the whole structure of exploitation (planks, thick planks, laths, sawdust, coarse waste). Let us point out that the cross section of the logs is considered an ideal circle. Figures 3 and 4 show the sawing dispositions, as well as data concerning the specimens sawn, fine and coarse waste from treatment of white pine logs with diameter of 37,0 to 52,0 cm. (Table 1 and Table 2)

Structure of sawn wood and waste in pine log, diameter dsr = 37cm

Log volume: $V = 0{,}430\ m^3$

Sawing dispositions: $\frac{R}{25}, \frac{1}{100}, \frac{R}{25}$ $\frac{R}{25}, \frac{3}{100}, \frac{R}{25}$



$$\frac{4}{25},\frac{1}{100},\frac{4}{25}$$

$$\frac{3}{100},\frac{1}{25}$$

Figure 3. *Structure of sawn wood and waste in pine log, diameter 37,0 cm*

According to Log length: $\frac{3}{100} \Rightarrow l = 4{,}0$ m; $\frac{6}{25} \Rightarrow l = 4{,}0$ m; $\frac{3}{25} \Rightarrow l = 3{,}0$ m

Table 1. *Structure of sawn wood, laths,sawdust and coarse waste, in pine log, diameter 37,0 cm*

STRUCTURE OF SAWN WOOD (1)

	Mmark	**thickness [m]**	**width [m]**	**length [m]**	**volume [m^3]**
1	1	0,025	0,140	3,0	0,011
2	2	0,025	0,210	4,0	0,021
3	3	0,025	0,280	4,0	0,028
4	4	0,025	0,310	4,0	0,031
5	5	0,025	0,310	4,0	0,031
6	6	0,025	0,280	4,0	0,028
7	7	0,025	0,210	4,0	0,021
8	8	0,025	0,140	3,0	0,011
9	9	0,100	0,100	4,0	0,040
10	10	0,100	0,100	4,0	0,040
11	11	0,100	0,100	4,0	0,040
12	12	0,025	0,100	3,0	0,008
13	13				
14	14				
15	15				
16	16				
17	17				
				Total (1)	**0,309 m^3**
	PERCENT IN RELATION TO V:				**71,77 %**

LATHS (2)

	quantity	thickness [m]	width [m]	length [m]	volume [m^3]
	10	0,025	0,025	1,0	0,006 m^3
				TOTAL (2):	**0,006 m^3**
	PERCENT IN RELATION TO V:				**1,45 %**

SAWDUST (3)

		∑h of sawing [m]	l of sawing [m]	b of sawing [m]	Volume [m^3]
		2,736	4	0,0022	**0,024 m^3**
	PERCENT IN RELATION TO V:				**5,60 %**

COARSE WASTE (4)

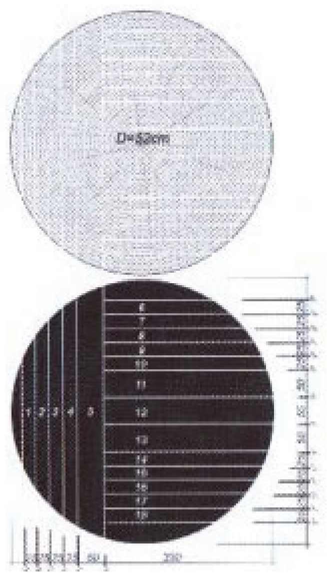
Course Waste (4) = V – (1+2+3) =		**0,091 m^3**
	PERCENT IN RELATION TO V:	**21,18 %**

Max quantitative exploitation (1+2) P = 73,22%
Coarse Waste and Sawdust (3+4) P = 26,78%

Structure of sawn wood and waste in pine log, diameter dsr = 52cm

Log volume: V = 0,849 m^3

Sawing dispositions: $\frac{R}{25}, \frac{1}{50}$ $\frac{R}{25}, \frac{3}{50}, \frac{R}{25}$



$\frac{4}{25}, \frac{1}{50}$ $\frac{5}{25}, \frac{3}{50}, \frac{5}{25}$

Figure 4. *Structure of sawn wood and waste in pine log, diameter 52,0 cm*

According to Log length: $\frac{4}{50} \Rightarrow l = 4{,}0\,\text{m};\ \frac{11}{25} \Rightarrow l = 4{,}0\,\text{m};\ \frac{3}{25} \Rightarrow l = 3{,}0\,\text{m}$

Table 2. *Structure of sawn wood, laths,sawdust and coarse waste, in pine log, diameter 52,0 cm*

STRUCTURE OF SAWN WOOD (1)

	mark	**thickness [m]**	**width [m]**	**length [m]**	**volume [m^3]**
1	1	0,025	0,16	3,0	0,012
2	2	0,025	0,25	4,0	0,025
3	3	0,025	0,33	4,0	0,033
4	4	0,025	0,38	4,0	0,038
5	5	0,050	0,41	4,0	0,082
6	6	0,025	0,19	4,0	0,019
7	7	0,025	0,23	4,0	0,023
8	8	0,025	0,26	4,0	0,026
9	9	0,025	0,28	4,0	0,028
10	10	0,025	0,29	4,0	0,029
11	11	0,050	0,31	4,0	0,062
12	12	0,050	0,32	4,0	0,064
13	13	0,050	0,31	4,0	0,062
14	14	0,025	0,29	4,0	0,029
15	15	0,025	0,28	4,0	0,028
16	16	0,025	0,26	4,0	0,026
17	17	0,025	0,23	4,0	0,023
18	18	0,025	0,19	4,0	0,019
				Total (1)	**0,628 m^3**
	PERCENT IN RELATION TO V:				**73,96 %**

LATHS (2)

	quantity	thickness [m]	width [m]	length [m]	volume [m^3]
	16	0,025	0,025	1,0	0,010 m^3
				TOTAL (2):	**0,010 m^3**
	PERCENT IN RELATION TO V:				**1,18 %**

SAWDUST (3)

		∑h of sawing [m]	l of sawing [m]	b of sawing [m]	Volume [m^3]
		5,460	4	0,0022	**0,048 m^3**
	PERCENT IN RELATION TO V:				**5,66 %**

COARSE WASTE (4)

Course Waste (4) = V – (1+2+3) =	**0,163 m^3**
PERCENT IN RELATION TO V:	**19,20 %**

Max quantitative exploitation (1+2) P = 75,14 %

Coarse Waste and Sawdust (3+4) P = 24,86 %

3. RESEARCH RESULTS

Having applied the technological procedure and sawing dispositions, we will here provide the results of the experimental tests and simulation in sawing white pine logs.

Firstly, we will present the data related to the raw material. It is given in Table 3. The table contains the thicknesses of the classes, number of samples, their grade, mean diameter, length and volume of logs. The total quantity of logs was distributed into 5 (five) thickness classes.

The logs belong to class I/Π quality, 4,0 m. long and with diameter ranging between 25,0 cm. to 75,0 cm. From each thickness class 10 samples were analyzed, which totals to 50 logs (column 3). The volume, depending on the diameter and length of the logs, varies from 0,196 m^3 and 1,610 m^3 In the same column (column 7) is put the total volume of the logs amounting

33,645 m. Products obtained from sawmill treated logs are planks, thick planks, beams, laths, fine waste (sawdust) and coarse waste (plywood pieces , cut-offs, cut-outs and lids).

Our attention is primarily focused on the results on max quantitative exploitation and comparison of the data on experimental and simulated research.

In order to simplify the comparison of the results on using wood in an experimental way with the results obtained from the programme simulation-SBG", and to make them clear to see, they are shown in Table 4. The same table also gives the mean statistically calculated values of quantitative exploitation. Our conclusion was that with the programme "simulation-SBG" higher values for max quantitative exploitation were obtained, varying between 1,93%and 3,16%. For better presentation and comparison of the quantitative exploitation regarding the thickness classes, the values obtained from practical testing and those from simulation of treatment are presented in Figure 5. The complexity of the research (experimental/simulation-SBG) is supported with results on minimum, maximum and mean values of quantitative exploitation, sawdust, coarse waste and total waste. These values are presented in Table 5. With the programme "simulation-SBG", the minimum quantitative exploitation value is 68,33%, the maximum one is 78,00% and the mean one is 74,43%. As to experimental research, the values are slightly lower, being 66,82%, 76,43% and 71,86 for the minimum, maximum and mean value respectively. The data on sawdust in simulation of process vary between 5,5% and 6,36%, the mean value being 5,87%. With experimental research, the values range from 8,93% to 11,30%, the mean value being 10,18%. The coarse waste (programme "simulation-SBG") has a minimum value of 16,50%, maximum value of 24,81% and mean value of 19,20%, thus having slightly higher values than the ones obtained in an experimental way, which are between 12,27% and 23,97%, the mean value being 18,19%. The total quantity of waste is inversely proportional to the max quantitative exploitation.

***Table 3.** Data regarding white pine logs*

Ord. No.	**Thickness class [cm]**	**Number of samples N**	**Mark**	**Dimensions**		**Volume V [m^3]**
				Mean diameter Dsr [cm]	**Length L [m]**	
1	2	3	4	5	6	7
1	25.0 ÷ 35.0	10	I	25.0	4.0	0.196
			II	33.0	4.0	0.342
			III	35.0	4.0	0.385
			IV	28.0	4.0	0.246
			V	30.0	4.0	0.283
			VI	32.0	4.0	0.322
			VII	34.0	4.0	0.363
			VIII	25.0	4.0	0.196
			IX	33.0	4.0	0.342
			X	31.0	4.0	0.302
2	35.1 ÷ 45.0	10	I	36.0	4.0	0.407
			II	37.0	4.0	0.430
			III	39.0	4.0	0.478
			IV	44.0	4.0	0.608
			V	43.0	4.0	0.581
			VI	36.0	4.0	0.407
			VII	42.0	4.0	0.554
			VIII	41.0	4.0	0.528
			IX	40.0	4.0	0.502
			X	36.0	4.0	0.407

3	45.1 ÷ 55.0	10	I	46.0	4.0	0.664
			II	48.0	4.0	0.723
			III	52.0	4.0	0.849
			IV	46.0	4.0	0.666
			V	46.0	4.0	0.664
			VI	53.0	4.0	0.882
			VII	50.0	4.0	0.785
			VIII	47.0	4.0	0.694
			IX	49.0	4.0	0.754
			X	54.0	4.0	0.916
4	55.1 ÷ 65.0	10	I	56.0	4.0	0.985
			II	58.0	4.0	1.056
			III	65.0	4.0	1.327
			IV	63.0	4.0	1.246
			V	60.0	4.0	1,130
			VI	57.0	4.0	1.020
			VII	56.0	4.0	0.985
			VIII	60.0	4.0	1.130
			IX	61.0	4.0	1.168
			X	58.0	4.0	1.056
5	65.1 ÷ 75.0	10	I	69.0	4.0	1,.494
			II	66.0	4.0	1.368
			III	67.0	4.0	1.409
			IV	66.0	4.0	1.368
			V	68.0	4.0	1.451
			VI	69.0	4.0	1.494
			VII	66.0	4.0	1.368
			VIII	70.0	4.0	1.540
			IX	71.0	4.0	1.610
			X	68.0	4.0	1.451
6	**TOTAL**	**50**				**33.645 m^3**

***Table 4**. Quantitative exploitation, experimental/simulation-SBG*

Thickness class	**Quantitative exploitation**	
	Experimental	**simulation-SGB**
cm	**%**	**%**
1	2	3
25.0-35.0	66.82±1.11	68.83±0.31
35.1-45.0	69.65±0.99	72.81±0.55
45.1-55.0	72.30±1.03	75.40±0.61
55.1-65.0	75.15±1.37	77.08±0.35
65.1-75.0	76.43±1.46	78.00±0.21

***Table 5**. Mean values – quantitative exploitation, sawdust, coarse waste and total waste*

Research	Mean values											
	Quantitative expl.			Sawdust			Coarse waste			Total waste		
	x_{min}	x_{max}	$\dot{x}$	x_{min}	x_{max}	$\dot{x}$	x_{min}	x_{max}	$\dot{x}$	x_{min}	x_{max}	$\dot{x}$
1	2	3	4	5	6	7	8	9	10	11	12	13
Simul. SGB.	68.83	78.00	74.42	5.50	6.36	5.87	16.50	24.81	19.20	22.00	31.17	26.84
Experim.	66.82	76.43	71.86	8.93	11.30	10.18	12.27	23.97	18.19	23.57	33.18	28.36

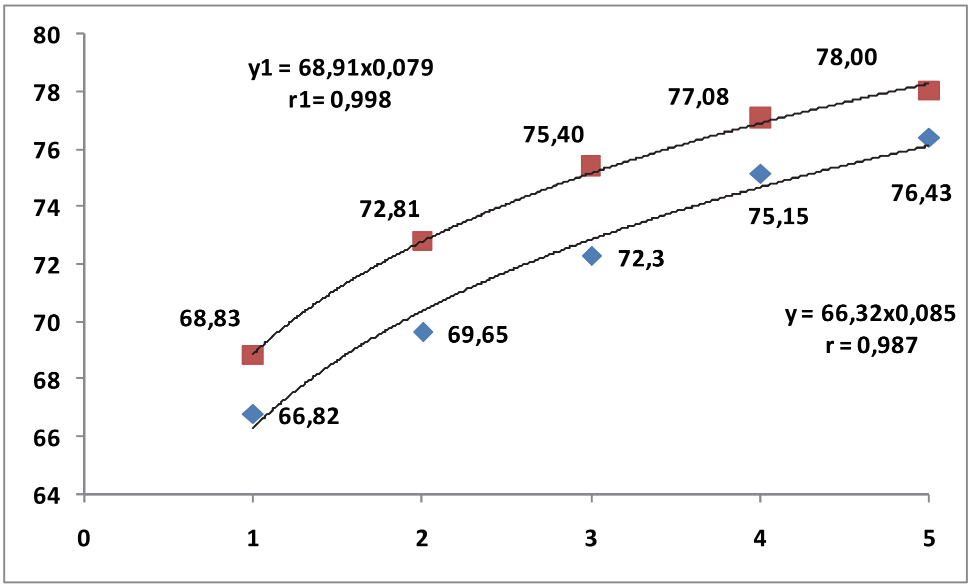


***Figure 5.** Relation between quantitative exploitation and thickness classes, experimental/simulation-SBG*

4. CONCLUSIONS

The results in this paper are primarily concerned with max quantitative exploitation. The analysis also includes the quantity of fine, coarse and total waste.

Identified conclusions:

1. Raw material to be tested, white pine logs. Quality class I/П. Length of 4,0 m.Diameter of 25,0 cm to 75,0 cm. The test covered 50 logs with total wood volume of 33,65 m^3.

2. Experimental (practical) tests:

– quantitative exploitation, within the limits of 66,82% to 76,43%. Mean value 71,86%;
– sawdust, from 8,93%, mean value 10,18%, to 11,30%;
– coarse waste, from 12,27%, mean value 18,19%, to 23,98%;
– total waste, from 23,57%, mean value 28,36%, to 33,18%.

3. Programme "simulation SBG":

– quantitative exploitation, minimum 68,83%, maximum 78,00%, mean value 74,42%;
– sawdust, from 5,50%, mean 5,85%, to 6,36%;
– coarse waste, from 16,50%, mean 19,20, to 24,81%;
– total waste, from 22,00%, mean 26,84, to 31,17%.

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BIOLOGICAL PROPERTIES OF BEECH WOOD MODIFIED BY CITRIC ACID

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ABSTRACT

The weight percentage gain (WPG) and biological durability against pure culture of mycelium of brown-rot fungus *Poria placenta* and against spore suspension of blue stain fungi of beech wood modified by citric acid was measured and results are presented. Biological resistance of modified wood against brown-rot fungus *Poria placenta* as well as against blue stain fungi is significantly increased compared to non-modified wood. Improved durability of modified wood against tested brown rot fungus remained unchanged after leaching. Results indicate modification by citric acid as a promising method, but further research on service life prediction through long term field testing is needed.

Key words: Biological durability, Blue stain, Chemical modification of wood, Citric acid, *Poria placenta*, Weight percentage gain (WPG)

1. INTRODUCTION

Research on the wood modification mostly deal with improvement of one or more of the undesired wood properties i.e. elimination or reduction of limitations of wood as a raw material. In general, modified wood is expected to be more dimensionally stable, more durable against blue stain and rot fungi, more resistant to UV radiation in comparison to unmodified wood. Mechanical properties should be unchanged or even improved. Ecological-economic justification of modification processes and chemicals is also requested. Today there are many different modification processes, and some of them are developed to the industrial production.

Thermal modification is a process where the wood cell wall polymers (especially hemicellulose, less lignin) are destructed to the radicals that repolymerise with OH groups of wood cell wall compounds only by heating. It is mostly conducted in operating cylinder at the temperatures between 150 and 260 °C without oxygen presence (Rapp and Sailer, 2001; Rep and Pohleven, 2001; Yildiz *et al.*, 2003).

Chemical modification implicates etherification, esterification or acetylation between some chemical and OH groups of wood. The chemical combined with adequate catalyst(s) reacts with OH groups of cellulose forming cross-linking between cellulose chains. Important parameters for successful chemical modification are the type of the basic chemical, temperature, processing time, type of catalyst and wood species. Modifications by some chemicals have problem with releasing formaldehyde at higher modification temperatures. Because of this problem, scientists are introducing new non-formaldehyde chemicals. One non-formaldehyde chemical is cyclic alcohol furfurol which can be easily produced from agricultural biomass. Wood furfurilation can result with huge weight percentage gain (WPG). Furfurilated wood has very good biological durability and dimensional stability. On one hand furfurol, as a cyclic chemical is capable of modifying lignin while many other wood modifying chemicals mainly modify holocellulose. On the other hand the main problem of this chemical is that it is susceptible to self-polymerisation. Although wood acetylation has been developed to the large scale production, there are still lots of problems with this process. Other non-formaldehyde

chemicals are polycarboxylic acids (PCA). The possibility of bonding PCA anhydride with OH groups of lignocelluloses ensures cross-link reaction, good bond stability and durability (Fang *et al.*, 1999). Cross-linking reaction between cellulose and PCA is esterification. By application of three-carboxylic acids, first anhydride arises from two neighbouring carboxyl groups for first bond creation, and the second anhydride arise from other two neighbouring carboxyl groups. This possibility of bonding the second anhydride with OH groups of wood ensures cross-linking, bond stability and durability (Bischof Vukušić *et al.*, 2006). Katovic *et al.* (2004), Bischof Vukusic *et al.* (2006), Hasan *et al.* (2006, 2007, 2012), Despot *et al.* (2008), Šefc *et al.* (2009, 2012) have esterified several wood species with citric acid (CA) and gained very good dimensional stability and biological durability, while micro tensile strength decreased for 30 %, and compression strength parallel to the grain stayed unchanged.
All of these chemical modifications have the same goal – to improve desired (targeted) wood property(s). Some studies on the influence of CA modification on physical and mechanical properties of wood have been already done. Preliminary results on the improvement of biological durability in lab conditions of beech wood modified by CA are presented.

2. MATERIALS AND METHODS

Beech wood (*Fagus sylvatica* L.) was used for this research. Beech is commercially most important wood species in Croatia and due to its' very low-durability it is prescribed as a reference low durable wood species in many European norms. Lattices were sawn from the region close to bark of one air-dried and afterwards kiln-dried beech plank. All specimens were cut, selected and marked axially and successively according to EN 113 (1996) and according to EN 152-1 (1988) (Table 1).

Table 1. *Type of test, modification paramethers and number of specimens*

Type of test	Modification Treatment Code	Modification parameters				Number of specimens
		Chemicals concentration [%]		Thermocondensation		
		CA	Catalyst	Temperature [°C]	Time [h]	
EN 113	MCA	10.5	7.5	140	10	14
	MCA L	10.5	7.5	140	10	14
	AHT			140	10	14
	Control	-	-	-	-	42
EN 152-1	MCA	10.5	7.5	140	10	10
	AHT	-	-	140	10	10
	Control	-	-	-	-	20

Chemicals, solutions, modification and leaching procedures

Water solution of 10.5 % of CA and 7.5 % of catalyst was prepared for modification. In standard climate conditioned specimens were full-cell impregnated with prepared solution. Afterwards specimens were slowly air dried and oven dried till constant mass and then thermocondensed in oven at 140 °C for 10 hours. Group of specimens was only air heat treated at the thermo-condensation temperatures (AHT) and used as a control of possible influence of temperature on biological durability. Afterwards WPG was calculated.

One group of MCA specimens aimed for leaching were conditioned at standard climate, and then leached (full-cell impregnated with distilled water and heated in oven at 60 °C for 48 hours). Every 12 hours the water was changed. Then the specimens were again air-dried and oven-dried to constant mass.Before biological durability testing all specimens were conditioned in standard climate to the constant mass.

2.1 WPG determination

Weight percentage gain of modified specimens (WPG) was calculated as a ratio of difference of oven-dried mass after modification (m_2) and oven-dried mass before modification (m_1) and m_1 (1).

$$WPG = \frac{m_2 - m_1}{m_1} \times 100[\%] \quad (1)$$

2.2 Biological durability determination

Determination of biological durability of CA modified wood against pure culture of brown-rot fungus *Poria placenta* (Fries) Coke sensu J.Erikson was done according to EN 113 (1996). “Potato dextroze agar (PDA)” by OXOID was used as a nutrient medium. Mass loss of specimens caused by fungal nutrition (d*m*) was calculated by dividing the difference of oven-dried mass of specimens after fungal nutrition (m_4) and starting mass (m_2) with starting mass (2).

$$dm = \frac{m_2 - m_4}{m_2} * 100[\%] \quad (2)$$

The durability test against spore suspension of blue stain fungi *Aureobasidium pullulans* (de Barry) Arnaud and *Sclerophoma pithyophila* (Corda) Hohn. was performed in liquid nutrient medium of “Malt extract” (by OXOID) and results were evaluated according to EN 152-1 (1988).

3. RESULTS AND DISCUSSION

Looking at *WPG* of different wood species after the same modification with CA, it is visible that fir-wood had the greatest *WPG*, while the beech-wood had the smallest *WPG*. These data suggest that *WPG* depends on the density of wood as well as on concentration of CA in water solution. Air heat treatment (AHT) resulted with almost the same average mass loss of pine and beech wood (Table 2).

Table 2. *WPG of different wood species modified by different concentrations of citric acid*

Modification type	WPG mean value [%]	Source
MCA Fir*	17.9	Šefc (2006)
MCA Pine*	12.4	Hasan *et al.* (2006, 2007)
AHT Pine	-0.3	
MCA Beech*	6.1	Despot *et al.* (2008)
AHT Beech	-0.3	
MCA Beech**	14.8	

* c(CA) = 7,5 %; ** c(CA) = 10.5 %

On one hand, according to Rapp and Sailer (2001), at increasing wood mass loss during oil heat treatment (OHT), biological durability of OHT wood also increases. On the other hand, Rapp and Sailer (2001) and Hasan *et al.* (2006) reported no difference in biological durability between the AHT wood modified at lower temperatures and non-modified controls.

Results of this study confirm no significant difference in biological durability between AHT and control specimens for tested modification regime. In the same time MCA specimens did not change resistance after one cycle of leaching. These results indicate that statistically high significant difference in biological durability of MCA specimens against tested brow rot fungus is exclusively the result of cross linking of CA on OH groups of beech wood components and that the bond is stable and resistant to hot water (Figure 1).

Pine sapwood modified with CA with *WPG* of 12.4 % reached 5.3 times greater biological resistance against *P. placenta* (Hasan *et al.*, 2006). Beech wood modified at the same regime resulted with *WPG* of 6.1 % and 8.3 times greater biological resistance against the same fungus (Hasan *et al.*, 2007) and beech wood modified with CA at *WPG* of 14.8 % resulted with 9.2 times greater biological resistance against the same fungus. It leads to the conclusion that modification of beech wood with CA is effective even at lover *WPG*.

Results of this experiment shoved that this regime of modification of beech wood by CA also significantly improved resistance against staining fungi, while thermocondensation itself had small effect on resistance improvement (Figure 2).

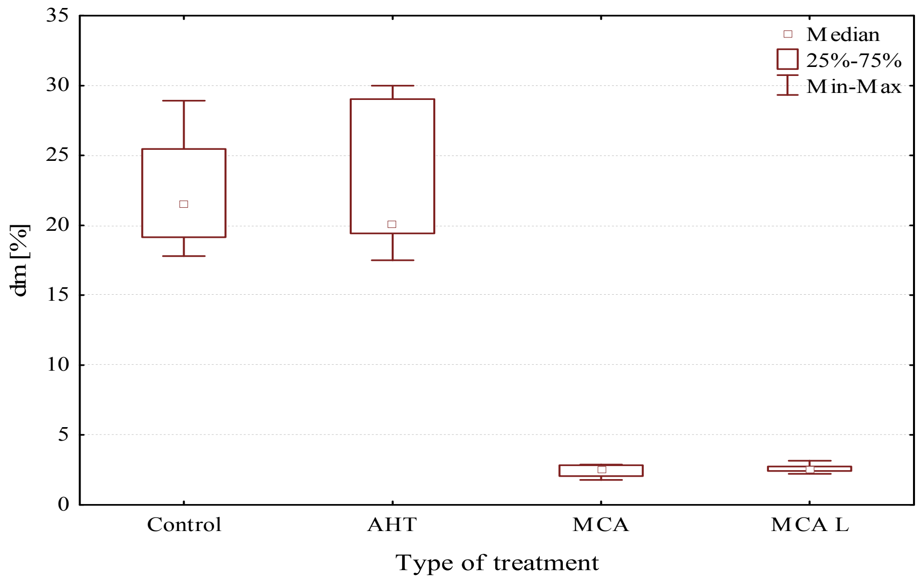

Figure 1. *Mass loss of differently modified and control beech wood caused by the fungus Poria placenta*

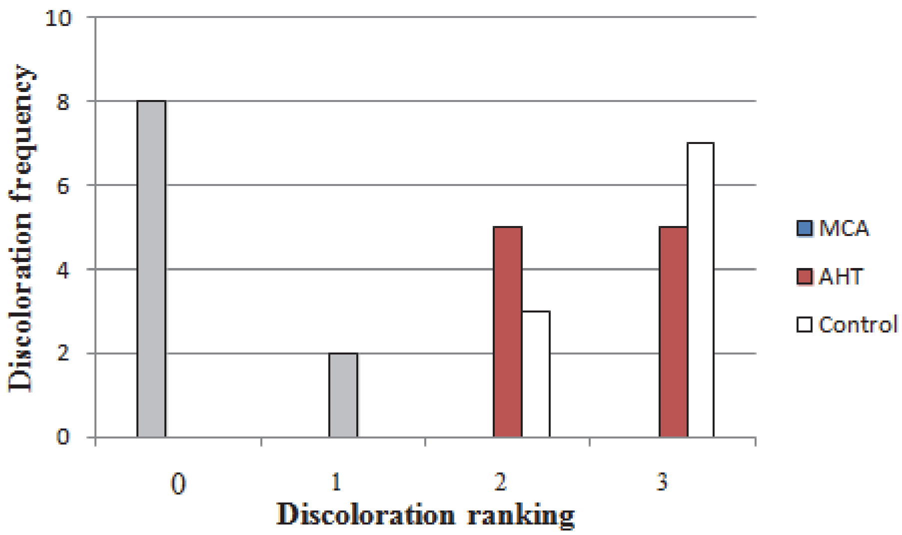

Figure 2. *Frequency of discoloration of differently modified and control beech wood caused by staining fungi*

Comparing the results from the literature and the results of this experiment it can be concluded that by increasing the *WPG* during modification by CA, biological durability also increases but not proportionally. It is to expect that even greater *WPG* will result with greater biological resistance. In this way biological durability of wood modified by CA could be even more improved. However the results of the blue stain test are preliminary and based only on visual observation of the surface of the specimens. Therefore it is recommended also to evaluate the interior of the specimens and determine the depth of the staining penetration into modified wood as it is described in the EN 152-1.

4. CONCLUSIONS

Biological durability of beech wood modified by citric acid (CA) against tested brown rot fungus *Poria placenta* and against blue staining fungi is significantly increased and it did not significantly change after leaching in hot water. Weight percentage gain (*WPG*) of 14.8 % resulted with nine time greater biological resistance against tested basidiomycetes fungus in comparison to unmodified controls.

Combining the concentrations of citric acid and catalyst in water solution and by optimisation of impregnation procedure, temperature and time of thermo-condensation it would be possible to optimise desired wood properties.

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INFLUENCING PARAMETERS IN SELECTING THE TYPE OF FLOOR AND KIND OF ADHESIVE IN WOODEN FACILITIES

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ABSTRACT

Wooden facilities can be applied for the holidays and living. Depending on the usage, construction technique, and the required quality and durability of the building, different types of flooring and the adhesives are used. The paper presents the parameters that influence the choice of the floor and adhesive to achieve the desired quality of living in the facilities and the durability of the facility.

Key words: types of floors, types of adhesives

1. INTRODUCTION

Properly designed, constructed and maintained wooden floors belong to the most decorative floor surfaces. Wood is actually the one visible, the final layer of composite floor, and it is also an element of architecture. When selecting wood, except for colours and types, a crucial role should have a anticipated place of installation and improvement of loads that will take effect on it within a specified period of usage. When embedded into the floors it is particularly important for wood to be adjusted with the tone and tradition of the region for usage. Many people choose wooden floors instead of the textile ones because of traditional applications of typical floor elements, such as parquet floors, in residential areas during the last few generations. However, the choice of a particular type of wood for the floor is often based on its colour, rather than on technical characteristics. Colour of the floor is determinated by fashion, so every few years we are convinced that bright and shiny colours are required, or dark and dull species of wood. Wood flooring are glued to the surface by various adhesives. Commonly being used adhesives are dispersion, reactive and elastomeric adhesives.Dispersion adhesives are usually made based on aqueous dispersion of polyvinyl acetate, the ones that react are usually made of polyurethane or epoxy, production of Elastomeric adhesive is mostly based on synthetic rubber. Adhesives for bonding floors to the substrate must be compound and ready so to be able to,on the cohesion and adhesion base, connect wood with the ground in a satisfactory manner.

2. CHARACTERISTICS AND PARAMETERES OF WOODEN FLOOR SELECTION

One of the segments of the usage of wood in construction is the construction of floors, on the traditional way from solid wood or the more modern, which includes the creation and installation of various types of industrial wood, such as plywood, laminates, etc. Floors and floor coverings by nature of their position in the area are objects that need to withstand the most adverse conditions.

This is the main reason why it must be made of high quality, healthy and long-lasting materials. Floors can be classified by material (wooden, concrete, etc.), methods of implementation (self-founded), form elements (parquet, decking), or by various other properties (hot, hygienic, wear-resistant, waterproof, swimming, etc.).

Wooden flooring is also important for natural lighting and indoor air quality. If the floor area in front of windows or glazed doors is not covered with a thin floor covering, lacquered floor will boost the glow of natural light further into the room. You need to find a middle ground between a matte surface and excessive gloss that can be undesirable as much as the repressed natural light. Patch on the floor can replace flooring ornament.

The most famous examples are the parquet floor mosaics that are processed on CNC machines in various forms. The development of technology every day erases the distinction between the floors of solid natural wood and composite wood-based products that are produced by using the most modern technologies and make the synthesis of the best features of wood and artificial materials. On the other hand, and totally natural wood is treated and processed so that its characteristics are improvedand more similar to artificial materials.

We distinguish the following types of wooden floors [4]:

- Suspended floor in which the panel of the floor is attached to a series of beams,
- Floating floor where the floor panel is attached to the insulation layer above the settlement below the floor or on a series of beams (bush) between which stands a layer of insulation,
- Top panel that is attached to the existing floor (usually floating) to improve surface quality and to improve the sound insulation,
- Raised floors where the floor segments are supported by short pillars to allow access of cables positioned below the roadway lining and,
- Industrial floors withplatformsthat include semi floor and deposit of floor bearing.

Depending on the permissible stresses three types of flooring are projected [4]:

- floors of residential buildings for which the maximum load does not exceed 1,5 [kN/m^2] and the maximum concentrated load does not exceed the value of 2,7 [kN/m^2],
- lightweight non-residential floors where the maximum load of 2,5 [kN/m^2], and the maximum concentrated load of 2,7 [kN/m^2],
- non-residential hard floors where the maximum load greater than 2,5 [kN/m^2] and the maximum concentrated load of 2,7 [kN/m^2].

Selecting the right floor is one of the most important aspects of designing facilities. The criteria that must be considered when choosing flooring should have been taken[5]:

- Impact resistance,
- Elasticity of lacquer,
- Wear resistance,
- Thickness of film,
- Adhesion.

Impact resistance tests consist of putting the balls of a certain mass and diameter that falls from various heights on the tested surface. The drop height is increased in steps of 50 mm to the determination of the maximum height of those height that do not yet led to the formation of any cracks on the impacted place. Relevant concentric circular cracks length is greater than 2 mm.

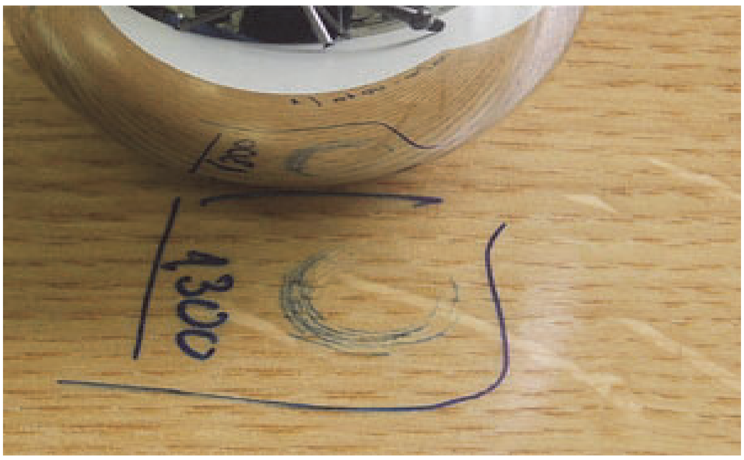


Figure 1. *Impact resistance test method* [5]

Elasticity of lacquer is determined by indentation on the surface of steellacquer block on whose face stands out 12 cones of different angles and heights (from 0.4 mm to 2.6 mm). Block is pressed on the universal machine for mechanical testing of wood with working speed of motion of the working head of 10 + 5 mm / min until complete contact of blocks'base with the face of probe.

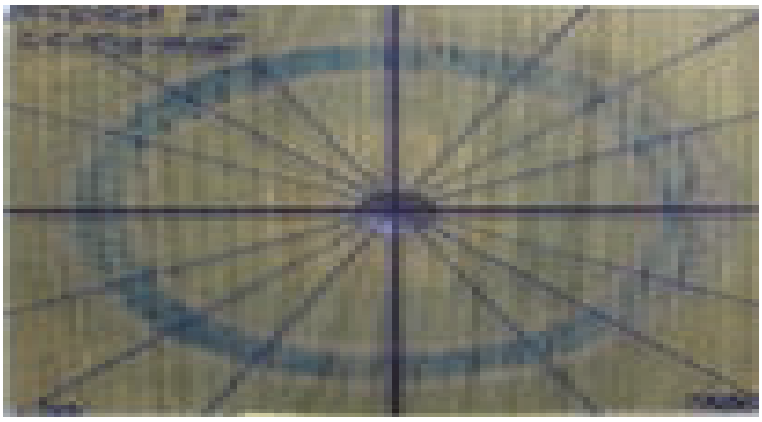


Figure 2. *Elasticity of lacquer testing* [5]

There are a number of methods for determining the resistance to wear (abrasion), but appreciated is the use of the device for testing Taber used with a variety of abrasive (friction) wheels. Generally, the test is carried out so that the probe is placed on a rotating table, load by testing abrasive wheels and additional weights and is submitted to rotation.

Dry film thickness provides the desired aesthetic appearance, but also affects the technical characteristics as well as the durability of wooden flooring. It directly depends on the amount of sediment, the depth of penetration of the base deposit, content of lacquer substance, the amount of film removed by grinding and the number of layers.

One of the most important quality features of varnished flooring is adhesion i.e. grit of adhesion of hardened film on the surface. Result of poor adhesion is often peeling of dry film which can occur very soon after the curing of lacquer, even in conditions of normal use.

When choosing wood for the production of walkway covering relevant are those properties of wood, which ensures good stability and durability of the floor structure and the most important feature is the resistance of the load. Persistent and permanent walkway coverings are made of wood with higher density (700 – 800 [kg/m^2]). [4]

Wooden floor installation began with mechanical fixation (in the past have wooden flooring nailed to the surface) or drenched in sticky bitumen pitch. Later they stiff glues for wood floors appeared as well as a system of floating installation without fixing the laminate and completed floors.

All these methods of installation have occasional drawbacks, such as: cracking, creaking mechanically fixed floors, the effect of rocking high-reflective sound in space with floating floors installed, plus damage to the surface caused by the transfer of stresses in bonding wooden floors with rigid adhesives. Therefore, it is accepted optimal method and most professional way to set up wooden flooring glued with elastic adhesives.

Proper surface preparation is the base for the successful laying of floor coverings. This work includes the use of the product for impregnating of absorbent surfaces. Because it often happens that users accept with scepticism the manufacturer's data about consumption of parquet adhesive. It is often forgotten that the data on the consumption of adhesive is only valid when the surface is flat and impregnated.

The importance and advantage of using impregnation before bonding parquet is following:

- impregnation firms substrate (penetrate deeply into the substrate and thus connect and fix any loose particles and reduces surface dust,
- impregnations reduce and equalize the absorption of surface (thus significantly reducing the consumption of adhesive that allows the formation of a compound with a smaller and more equal amount of adhesive).

When it comes to bonding parquet on non-absorbent substrates such as ceramic or stone, water from dispersion adhesive absorbs only the parquet, and then it almost certainly leads to a lifting of parquet. Proper selection is a two component adhesive that contains no water and quickly crystallizes. So, regardless of whether it is a dispersion or two-component adhesives surface should be well prepared for gluing to be successful. If the flooring is applied only to the levelling mass it is mandatory to follow the manufacturer's instructions depositing of mass and its preparation for bonding parquet.

3. TYPES AND CHARACTERISTICS OF ADHESIVE THAT ARE USED IN MAKING AND INTAGRATION OF PARQUET FLOORING

Adhesives in the timber industry are an important factor in the rationalization of raw materials and finished materials. Since ancient times, man has used the natural glue or glues based on starches, blood and other natural binders that are not toxic or emit substances that contaminate the working environment or the product. However, in the era of industrialization began production of synthetic glues and other adhesives that are based on a variety of chemical substances. These adhesives initially had only the task to provide a chemical and mechanical bond. However, 70 s and 80 s regulations regarding to quality and emissions of toxic substances have set a number of restrictions on chemical and mechanical properties of the adhesive, and permitted concentrations of certain substances, flammability and explosiveness for various types of adhesives [1].

3.1 Adhesives and process of bonding

Adhesives are materials that in certain circumstances, either because of chemical reactions, either because of the influence of temperature in terms of heating and cooling are characterized by hardening (solidification) and mutual strong bonding of identical or different materials. The main substance of each adhesive is binder that has animal, mineral and synthetic origin. In addition to binders, adhesives have other components such as solvents, plasticisers, fillers and hardeners.

Table 1. *Classification of adhesives by the ability of adhesion*

Adhesive type	Class	Reach of temperature (^oC)
1	1P, 1H, 1PH	- 60 do + 70
2	2P, 2H, 2PH	- 60 do + 70
3	3P	- 60 do + 70
4	4P, 4H, 4PH	- 60 do + 150
5	5P	- 60 do + 220
6	6P	- 60 do + 350

The number of species is determined by the ability of adhesion to satisfy specific criterion forces (For elastic bending and flaking) for period of exposure to 1 000 h at maximum temperature for each type.

Letters for class are defined by this classes [3]:

- CLASS P- gripping panels on the panel at the junction (according BS185),
- CLASS H- gripping to the surface on the surface of,
- CLASS PH – gripping suitable to class P and class H.

Under gluing of wood implies a firm surface connecting of two wooden surfaces by glue. Between these surfaces is a thin (optimal) adhesive. Given that is the wood surface, wooden surfaces is porous, the adhesive layer goes into the pores of the wood and when the adhesive layer hardens, it creates a network of branches in the pores of both wooden surfaces. When connecting or bonding of wood attractive forces called cohesion and adhesion interact, so that they create a chemical-mechanical connections that provide strength of adhesive joint [2].

Therefore, wood and glue must be in very close touch by the external pressure while the glue is still in a liquid state. It is important that the adhesive layer moisturize wood during the gluing process and penetrates into the wood, and to establish contact between the two substances. If the adhesive does not moisturize the wood, there is a repulsive acting force between the molecules and the creation of dispersion forces. Given that most of the wood adhesive are colloid solution that in the process of bonding change from liquid into a gel, and then harden, so that it becomes a strong adhesive compound.

This compound is reversible (if the adhesive layer is dissolved in water), or vice versa irreversible. Penetration of glue into the pores of the wood depends on the viscosity of the adhesive, the size and duration of the pressure. Viscosity of adhesive quickly decreases when the temperature increases, so you should take care of the optimum viscosity for all kinds of applications in bonding.

3.2 Characteristics and types of adhesives for parquet installation.

In general, bonding in many areas of human needs and in the economy represents a very important area which satisfies the needs of some relatively large economic sectors and citizens. In the last 30 years, it tremendously increased usage of adhesives globally. This was mostly contributed by enormously increased consumption of wood, which is related to the increase in people's living standards and the mismatch between the need for permanent preservation of the wooden stock and satisfaction of human needs for wood [1].

Characteristics of each adhesive determine its use and purpose. They can be summarized as follows:

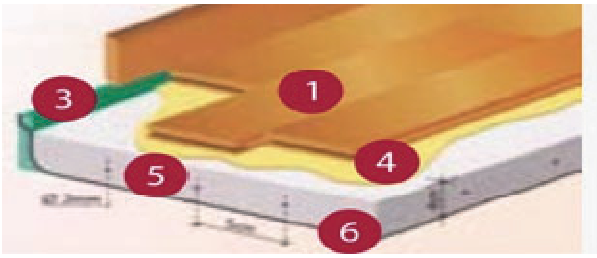
- Open time,
- Bonding time,
- Viscosity and thixotropy,
- Pot life,
- The impact on the dimensional stability of wood,
- The flexibility and resilience,
- Resistant to aging and heat resistance,
- Resistant to moisture,
- The strength of bonding,
- Compatibility with adhesive screed and type of wood,
- conditions of deposit.

Given the scope, technology requirements and conditions for the quality and consistency of quality ofbonding there is large number of adhesives, so that we can use for a wide selection and it is only necessary to know the technical and other requirements, and they can be obtained without difficulty and successfully applied [1].

With regard to the composition, the adhesive used for bonding parquet can be divided into the following three groups:

- Dispersion adhesives,
- Solvent Adhesives,
- The reaction adhesives.

It is generally used two types of adhesive when laying wooden flooring: dispersion glues and adhesives with reactive resins. Whenever applicable, dispersion adhesive must be given priority over other products because of its environmental friendliness.



1. Massive parquete, 2. Bond, 3. Corresponding adhesive, 4. Cemented surface
5. Under layered panels

Figure 3. *Laying solid wood parquet* [5]

Considering the exposure and complex process for quality usage of adhesive and good use of technological equipment it is necessary to know the basic theory of bonding, properties and characteristics of the adhesive bonding regimes, good blend and conditions in which will be extracted bonded materials or compounds in products and building construction. For good bonding is first necessary to choose the appropriate adhesive depending on materials that are bonded and bonding requirements and desired characteristics of bonded assemblies.

3.3. Characteristics and types of adhesives used for construction of finished parquet

The term finished parquet means parquet of different sizes and thickness, which was prepared for the laying and does not require any finishing. To differ from traditional occupations flooring (lamellar, lam-parquet, classic parquet of small and large format, etc.) For the depositing of flooring a lot of time is not required, because the panels are already drilled, machined and coated. So they just lie on the site and do not require acclimation to the area, which significantly shortens the entire process of installation of parquet. There are four base layer of parquet: We've got film, bonding layer(adhesive) , noble layer (wood), and finishing layer (lacquer).

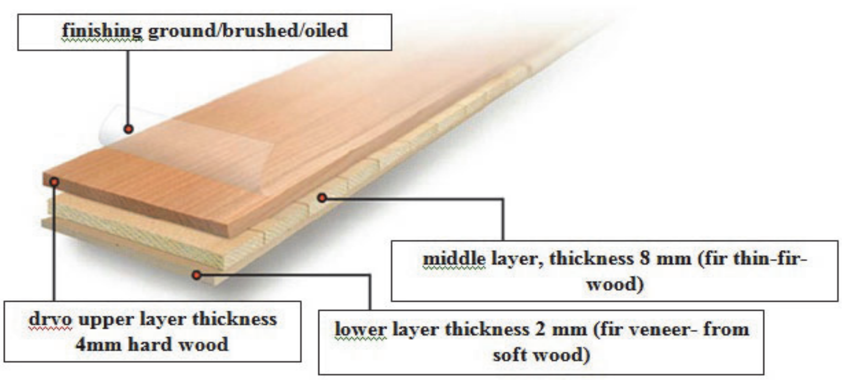


Figure 4. *Finished three-layer parquet floors* [5]

Base layer is the lower part of the parquet, or his rear side. It must provide dimensional and spatial stability, ensuring good adhesion to the substrate with different systems of deposit (gluing, nailing, clinging), but above all, must be resistant to moisture. It can made of natural wood or composed of multiple layers crossed with each other. It primarily used soft wood, because it contains the resin and is therefore more resistant to moisture, though it can be of different wooden board - hardboard, plywood, the plywood and related panel.

Bonding layer for multilayer finished parquet is the adhesive layer, which must guarantee good bonding and noble bearing layer. Adhesives that can be used for that purpose, depending on the chemical composition and properties of high build, divided into three main groups:

- Urea adhesives, whose bind is based on the chemical reaction of heat (they are the most common),

- Adhesives based on aqueous dispersions,
- Adhesives based on solvent.

In addition to its functional benefits, it should be noted that the aesthetic contribution of multilayer parquet to any space, especially for large rooms, is truly remarkable. This flooring gives exclusiveness to each business area, and to each home naturalness and warmth.

4. CONCLUSION

The natural colour and texture of the wood are the main aesthetic characteristics of wooden floors. Aesthetic values of wood are crucial factors in the competitiveness of wood compared to other flooring materials, such as textiles or ceramics. This is because the wood, in addition to its warmth, has an unusual natural unevenness of colour and texture, i.e. arrangement of anatomical elements on the surface is different. It is likable that each element of the wood floor varies, the wooden floor is variegated.

The epithet "warmth" of wood has a double significance. Some people "warmth" of wood is attached to the tactile sensation, and it's an experience you have when you touch the wooden floor, either by palms or feet. Given that the wood is relatively weak heat conductor, touching not deserve a lot of heat from the surface of the skin, so the sense of "warmth" wood is direct and pleasant. Other people under the warmth of wood include pleasant tones of natural wood colour, which are in widespread commercial tree species generally "warm" yellowish, brownish or reddish colour. This wood colour becomes one of the elements of a complex aesthetic perception of wooden flooring, experiences that are individually different, but mostly pleasant.

On the selection of the flooring main influence has:

- Type of the floor,
- The expected load on the floor,
- Characteristics of materials that the floor is made of,
- Characteristics of floors (toughness, elasticity varnish, wear resistance, film thickness, adhesion).

When installing the flooring it is necessary to pay attention on the preparation of the substrate, i.e. surface should be flat and impregnated as it is achieved:

- strengthens of the foundation (penetrating deep into the substrate and thus connects and fixes all loose particles and reduces surface dusting),
- Reduced and equalized substrate permeability (thus significantly reduces the consumption of adhesive and allows the formation of a compound with a smaller and more equal amount of adhesive).

To install parquet flooring it is used dispersion adhesives, solvent adhesives, reactive adhesives, and are essential to their following features: open time, bonding time, viscosity and thixotropy, time of mixing (pot life), the impact on the dimensional stability of the wood, plasticity and elasticity, resistance to aging and heat resistance, moisture resistance, bond strength, adhesive compatibility with screed and types, the conditions of deposit.

In preparing ready parquet with three layers it is applied urea adhesive that bind the basis of chemical reaction heat (they are the most common), water-based adhesives and solvent based adhesives.

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UDC 674.23

ANALYSIS OF FACTORS WHICH DETERMINE THE USE OF PARTICLEBOARD AND MDF AS RAW MATERIAL FOR FURNITURE MANUFACTURING

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ABSTRACT

Albanian industry of furniture manufacturing uses massively particleboards (Pb) and medium density fibreboards (MDF) as raw materials, whose imports reached a value of $ 8.2 million in 2009. A study was carried out to analyze he properties that determine the use of these panels in joinery. Tests included the most important physical and mechanical-technological properties. The study was focused on 18 mm thickness particleboard and 19 mm MDF. The whole process of panels sampling, test pieces preparation and their testing was performed according to EN standards. Results showed that panels fulfilled quality requirements specified by European standards. Bending strength of particleboards resulted 87% higher than EN reference value, whereas MDF about 50%. Tensile strength perpendicular to board's plane resulted 23% higher than the minimum limit for particleboard and 26% for MDF. Unlike veneer, which increased somewhat mechanical properties of the board, melamine didn't present any positive impact on its properties. MDF presented higher capability in screw holding than particleboard. Screw holding resistance in edge wasn't satisfactory for particleboard, but in plane presented values which must be taken into consideration. Quality of melamine lamination in particleboard resulted higher than veneer overlaying in MDF.

Key words: particleboard, MDF, properties, furniture.

1. INTRODUCTION

As key elements of furniture performance can be mention the resistance, solidity, weight, and its functionality. These elements are determined by the quality of raw materials, as well as by processing and assembling.

Furniture's ability to bear his weight and the weight of items placed on / in it depends directly on the resistance in static bending of the material from which it is built.

Furniture to be solid needs connections of its constituent elements to be more resistant. The quality of connection depends on the quality of material jointed together, as well as the quality of fastening element, Halebi (2006). Referring to time extension, the connection's quality depends on maintaining the original dimensions of jointed parts.

In case of dowel joints in particleboards (Pb), bonding of board's layers with each other presents a great importance. Weak resistance of this bonding causes destruction of the board where is mounted the fastening element, when a load is applied. As a consequence, the connection is destroyed and the furniture too. In this context information on tensile strength perpendicular to board's plane is very valuable, Semple *et al*. (2005).

With regard to screw connection applied extensively in handicraft furniture manufacture, information on wood material ability to hold screw is of crucial importance to ensure a connection with acceptable quality.

During its life the furniture is subject of different transport operations. In order its transportation to be easy and economical the furniture should be lightweight. The majority of constituent materials in furniture are wood based materials. As light is the wood material, as light is the weight of furniture.

Weight indicator of material is its density, a qualitative parameter of physical nature to determine the furniture quality.

In terms of appearance and functionality of furniture, these depend on the quality of design and appearances of its own material used for its production, and are mainly related to ability of designers.

Currently, Albanian manufacturing furniture industry use as raw materials massively particleboards and medium density fibreboards (MDF), which have replaced the solid wood and plywood, Ajdinaj (2006). Imported Pb and MDF by Albanian market reached a value of $ 8.2 million in 2009, and most of them were imported from Italy, Greece and Bulgaria, FAO (2010). In this context the knowledge and analysis of properties, which in itself are factors that determine the use of these panels in joinery, shall form the aim of our study.

2. MATERIAL AND METHOD

Analyses included a sufficient number of tests for significant physical, mechanical and technological properties of Pb and MDF, which are intended for use in normal conditions. These tests provided sufficient information for all Albanian furniture manufacturers who used these wood based panels as raw materials.

In Table 1 are presented tests carried out during the study accompanied by relevant EN methodological standards.

Referring to aim of the study, the performed tests were classified as comparative tests having as reference point the European classifier standards in power.

Table 1. *Typology of tests*

Test	Pb	MDF	Standard
Physical tests			
Density	√	√	EN 323
Swelling during water immersion	√	√	EN 317
Water absorption	-	√	ISO769
Mechanical and technological tests			
Static bending strength and modulus of elasticity	√	√	EN 310
Tensile strength perpendicular to board's plane	√	√	EN 319
Melamine surface soundness (peeling resistance)	√	-	EN 311
Veneer surface soundness (peeling resistance)	-	√	EN 311
Screw holding resistance	√	√	EN 320

2.1 Preparation of samples

The study was focused on Pb 18 mm thick and MDF 19 mm thick, which commonly are used as raw material for furniture production in Albania. Panels were provided by the company SHAGA, one of the major trading and manufacturing of furniture companies in the country. The selection of panels to be assessed as well as the selection and dimensions of samples prepared from these panels was performed according to procedures specified by the standards EN 326-1 and EN 326-3. The minimum quantity of samples for each type of tests was determined according to the standard EN 326-1.

In Table 2 are presented the minimum numbers of samples referring to respective tests. With regard to tests which were not shown in table, the minimum number of samples was given by the relevant methodological standard.

To determine those properties that vary according to two main directions of panel's plane (bending), two sets of samples were cut off according to longitudinal and perpendicular directions of the panel. Samples were cut off according to dimensions specified by the relevant standards. During preparation of samples was taken into account that minimum distance between two samples belonging to the same test should be 100 [mm].

Table 2. *Number of samples*

Test	Standard	Number of samples
Determination of density	EN 323	6
Determination of static bending strength and modulus of elasticity	EN 310	
Swelling after immersion in water	EN 317	8
Tensile strength perpendicular to board's plane	EN 319	

2.2 Physical tests

With regard to density, samples were prepared with size 50 × 50 mm. After conditioning, they were weight to 0.01 g accuracy and were measured in thickness up to 0.05 mm and other sizes up to 0.1 mm accuracy, according to EN 325 standard procedures. Density was calculated for each sample mean formula $D = \frac{m}{b_1 \times b_2 \times t} \times 10^6$ kg/m^3, where *m* was the mass of sample in g and b_1, b_2 and *t* were dimensions and thickness of the sample in mm.

Swelling was pointed out by measuring the increase in % of sample's thickness after immersion in water for 24 hours, mean formula $G_t = \frac{t_2 - t_1}{t_1} \times 100$, where t_1 and t_2 thickness of the sample before and after immersion in water, in mm. Samples were prepared in square shape with dimension 50 ± 1 mm and thickness was measured to the points of diagonals intersection by means of micrometer with 0.01 mm accuracy.

Water absorption was calculated for samples with dimensions 100 ± 1 mm, mean formula $T_u = \frac{p_2 - p_1}{p_1} \times 100$ %, where p_1 and p_2 were sample weights in g before and after 24 hour immersion in water.

2.3 Mechanical Tests

Determination of static bending strength and modulus of elasticity to the plane was performed according to standard EN 310. The principle of test consisted that strength and modulus of elasticity in bending were determined under the action of a load on the middle of sample of nominal thickness not less than 3 mm, positioned on two supports. Bending strength was calculated mean the ratio of bending momentum (M) of maximal load (Fmax) in transverse section of the sample; while modulus of elasticity was calculated mean the linear curve load - deformation. The result corresponded to visible elasticity module and not that real one, because the measurement was performed under the influence of bending and shear effects.

Knowing the value of modulus of elasticity allows us to know what relation between load and relative deformation should be, remaining always within the linear proportionality load -deformation. Tests were performed mean mechanical testing machine of maximal load up to 20 tons (Controlab, FRANCE), equipped with transdutor for measuring of samples deformation in the middle of the distance between two supports with accuracy 0.1 mm and the other one of pressure with accuracy measuring of 1% (Figure 1).

Samples were prepared from the same panel before and after laminating (Pb) or veneering (MDF), 50 ± 1 mm in width and length $l = 20t + 50$ mm, where *t* was thickness of the panel in mm.

The maximum bending strength was calculated mean formula $f_m = \frac{3F_{max} \times l_1}{2b \times t^2}$ N/mm^2, where *Fmax* was the force of sample's destruction in N, l_1 was the distance between two supports in mm, *b* and *t* were width and thickness of the sample in mm.

The modulus of elasticity for each sample was calculated mean formula $E_m = \dfrac{l_1^3 \times (F_2 - F_1)}{4b \times t^3 \times (a_2 - a_1)}$ N/mm^2, where F_2-F_1 was increase of force according to straight line of load-deformation graphic in N and $a_2 - a_1$ bending radius corresponding to F_2-F_1 in mm (Figure 2). In our case we referred to values respectively $F_1 = 10\%\ F_{\max}$ and $F_2 = 40\%\ F_{\max}$.

Figure 1. *Universal mechanical testing machine*

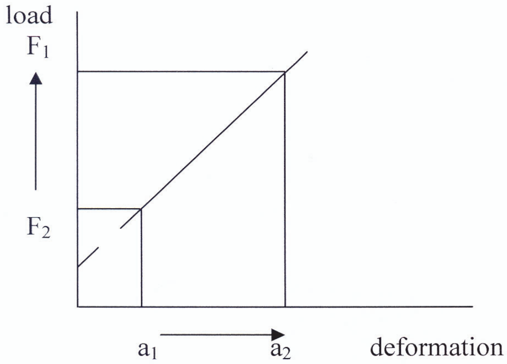

Figure 2. *Load – deformation curve within elastic deformation*

Tensile strength perpendicular to board's plane was measured according to EN 319 standard procedure. The principle of measurement consisted in evaluation of tensile strength's peak perpendicular to surface of the sample, on which a uniform traction force was applied, from starting of force until to destruction of the sample. The strength in this case was determined by the ratio between maximum load and surface sample. It should specify that this analyse provides information on shear strength of inner section of panel (for three layered Pb - middle layer) and not for surfaces layers of the panel.

For this test was used the same mechanical test machine as in the case of static bending, realising appropriate adaptations. Samples were cut off in square shape with dimension 50 ± 1 mm. Each sample was bonded in both sides with oak blocks mean epoxy glue. After adhesion, samples were conditioned for 24 hours and were tested. Tensile strength perpendicular to panel's plane, expressed in N/mm^2, was calculated by formula $f_T = \dfrac{F_{\max}}{a \times b}$, where $F_{\max}$ was the destruction in N and a, b were respectively the length and width of the sample in mm.

The overlaying test strength was performed according to standard EN 311 and consisted in measurement of the force needed to pull off a steel axe glued on overlaying panel surface, evaluating so the quality of adhesion between surface's particles or fibres and overlaying material.

There were cut off 10 test pieces with dimensions 50 × 50 mm from each sample. Samples were taken from overlaying panels, respectively:
- veneered MDF (company "ICA-ALBANIA");

Veneer thickness 0.6 mm, used glue urea formaldehyde (UF Kaurit). Temperature applied during hot pressing was 130 ºC, time pressing 1 minute. Gauge pressure applied by press, 250 bar.
- melamine Pb (company "FIRSTWOOD");

Melamine paper thickness and density respectively 0.2 mm and 178 g/m^2. Temperature applied during hot pressing was 198 ºC, time pressing 33 seconds. Gauge pressure applied by short cycle press, 250 bar.

In surfaces of test pieces were opened circular channels with inner diameter 35.7 mm. The surface of circular was 1000 mm^2 and depth of channel 0.3 ± 0.1 mm. Five channels were opened in upper surfaces and other fives in opposite ones. In limited areas of channels steel axis were glued (Figure 3). For technical reason dealing with test machine accessories, the axis length was not 26 mm, as specified to the standard, but 67 mm. Before adhesion, on axis surface was uniformly distributed an amount acrylic glue with two components. These glues were classified as the strongest glues recognized, Shields (1984). The axis was pressured on circular surface for more than 12 hours mean a hand grip device, in order to provide the maximum strength of adhesion.

After hardening of glue tests were carried out mean mechanical test machine (Figure 4). Overlaying strength (peeling resistance), expressed in N/mm^2 was calculated mean formula $S = \frac{F_{\max}}{A}$, where *Fmax* was destruction force in N and *A* circular area, 1000 mm^2.

Axial screw holding resistance was performed according to standard EN 320, for surface and edge. It should be noted that the standard was intended to be applied only on fibreboards, leaving to be implied that the use of screws in Pb fastenings is not preferred. But, based on the situation in Albania where screws fastenings of Pb are massively applied to handicraft furniture manufacturing, and noting that some certified laboratories in EU (CATAS etc.) apply this standard for Pb, was judged reasonable that Pb to be studied as well.

Figure 3. *Glued axis on test piece*

Figure 4*. Testing*

Screw holding resistance of surface and edges was determined by measuring the force required to pull off a specified screw from the sample of the panel. Holding resistance of edges was determined for panels of 15 mm thickness or greater. To perform this test was used the same mechanical test machine used for other tests, equipped with the appropriate accessories, which capture the screw to the bottom surface of its head and keep the sample fixed.

There were prepared 8 square shape samples (test pieces) with dimension 75±1 mm. After holes were opened, screws were mounted. The holes had diameter 2.7±0.1 mm and 19 ± 1 mm depth, perpendicular to sample surface, to the centre of the surface and to the mid-point of the edge. Steel screws were used with nominal dimensions 4.2 x 38 mm, with screw-thread n° ST 4.2, according to ISO 1478 and with 1.4 mm step fillet. Screws were inserted into the samples 15±0.5 mm. For each sample were performed 3 measurements, 1 for surface and 2 for edges respectively perpendicular to each-other. With regard to the edges the mean value of two individually measurements values was calculated.

3. RESULTS AND DISCUSSION

Mechanical testing data were received through LabView software and were processed in Excel. In Table 3 are presented results of laboratory tests (in parentheses standard deviations values are presented).

Table 3. *Results of laboratory tests*

Type of test	Unit	Pb		MDF	
		not laminated	laminated	not veneered	veneered
Density	kg/m^3	643 (25.4)	638 (22.5)	759 (18.4)	762 (19.8)
Swelling (24 hours)	%	11.3 (1.9)	11.2 (2.1)	10.2 (1.8)	10.8 (1.6)
Water absorption (24 hours)	%	-	-	14.7 (0.22)	14.1 (0.38)
Static bending strength	N/mm^2	24.3 (6.6)	23.8 (7.6)	29.4 (4.4)	35 (5.8)
Modulus of elasticity	N/mm^2	2212 (436)	2276 (312)	2909 (601)	3358 (737)
Tensile strength ⊥ to plane	N/mm^2	0.43 (0.11)	-	0.69 (0.12)	-
Overlaying strength	N/mm^2	1.72 (0.026)		1.53 (0.024)	
Surface screw holding	N	1346 (239)	-	1638 (287)	-
Edge screws holding	N	693 (201)		1204 (223)	

At first sight the results show that both types of studied boards have physical and mechanical parameters within limits specified by EN reference standards. An exception exists for swelling of Pb, for which the reference standard EN 312 does not give any reference value.

It is noted that some features represent significant higher values to the specified limits, especially those of mechanical properties. Pb static bending strength is about 87% higher than the minimum reference value, while for MDF about 50%. Modulus of elasticity results about 40% higher than the reference values for Pb and 30% higher for MDF. The same can be said even for values of tensile strength perpendicular to surface, where Pb appears to be 23% more resistant than the reference threshold, while MDF 26%.

Non laminated Pb presents almost the same swelling as that laminated one, whereas veneered MDF gives a swelling value 6% higher than non veneered one. Higher swelling of veneered MDF can be explained that veneer layers are swelled something more than panel, although it ought to be admitted that the difference is so small that it can be considered as deviation of the average value of swelling of panel itself.

Laminated Pb does not present any improvement of mechanical properties compared with non laminated one. In this case this phenomenon is related to the nature of overlaying material, which after hot pressing presents low resistance by mechanical viewpoint (it is very brittle). In a different way veneering is presented. It increases the panel's bending strength about 19% and its modulus of elasticity 15%. Veneer, serving as reinforcing layer, improves bending strength of the panel, although our data are lower than those of literature, Norvydas and Minelga (2006).

With regard to screws holding resistance MDF stay significantly higher than Pb, especially for edge case. MDF surface screws holding resistance is about 22% higher than that of Pb and in edge about 74% higher. This is explained by the fact that besides density, MDF has also more homogeneous structure, which makes possible a greater contact surface panel-screw than in Pb, causing so a greater relation force, Wang *et al*. (2007). Notable difference exists between surface and edge, where for Pb, the edge screws holding resistance is almost half of the surface one. In case of MDF this difference is 36%.

Overlaying strength is different to both panels. Laminated Pb presents a value 12% higher than veneered MDF. For both panel's type the overlaying strength appears to be good quality, because the destruction of all test pieces happen only in surface layers of the panel. Based on this fact, we can say that our values may also be used as an indicator for strength of surface layers of studied panels.

4. CONCLUSIONS

The results presented above, although referring to only a part of panels used for furniture manufacturing in Albania, provide useful information regarding to qualitative parameters of Pb and MDF.

From tests resulted that studied panels are within qualitative requirements specified by European reference standards. Panels are presented qualitative, especially to mechanical properties. Otherwise to veneering, which improves somewhat mechanical properties of the panel, melamine does not make any positive impact on its properties. MDF is presented more qualitative than Pb in screw holding resistance. Edge screw holding resistance of Pb does not appear a good quality, although the surface screw holding must be taken into consideration. The overlaying quality of Pb results higher than MDF.

We can say that the use of qualitative wood based panels, combined with a modern technology and appropriate marketing tools, has provided to some Albanian furniture manufacturing companies' success in international market.

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WEAR OF CART WHEELS IN LOG BANDSAW REASON FOR UNEQUAL THICKNESS OF BOARD IN BEECH

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ABSTRACT

Log bandsaws are most commonly used machines for cutting logs in the Republic of Macedonia. Movable parts, especially the cart to move, wear away in time. Increased wearing causes disrupted geometry of the raw material.

This paper presents the results of measurements of thickness of the planking stumps on both sides with 10 logs of beech.

Measurements show that the difference in thickness along both sides of the plank, regardless their cutting disposition, is about 2.0 mm for length of 4m; the difference in thickness on the transverse of the plank on its both sides is about 2.0 mm for width of 30 cm; the difference in thickness along the diagonal of the plank is insufficient and measures 4,5 mm, when the width of the plank ranges between 20 to 25 cm; the volume share of lower class planking thickness compared to the stump, expressed in percentage, is from 6 to 16%.

Keywords: bandsaw, cart , displacement, thickness, variability

1. INTRODUCTION

In wood sawing process of logs in the Republic of Macedonia, bandsaws are most commonly used.

Fitting the bandsaw and its cart must be done professionally and securely, so that we can get samples with parallel surfaces and right angles.

Control, maintenance and timely repairs are essential in order to avoid intolerable errors that can affect the dimensions of the samples almost as equally as when incompetently fitting a new machine. These errors also occur because of an unprofessional mishandling of the machine. They are often reasons for failures and further operation delays too, that only produce losses in the operation of the company. They must be immediately eliminated.

2. PURPOSE OF RESEARCHES

In this research we will consider the accuracy of the thickness of the planking stumps (thick plank/55 mm) obtained by sawing with a bandsaw. Because of the manner of individual sawing, these samples are always subject to cumulative set of anomalies when sawing the previous samples of the same log. Very often the first cuts and the last one are at 180^{o} angle. In the process, the small changes in geometry double due to wearing of the cart. It all reflects in a significant change in the geometry of the samples.

That is why the main purpose of this research will be the impact of wearing of the cart of a bandsaw on the variability of the samples' dimensions.

3. RESEARCHES TO DATE

While analyzing the available domestic and foreign textbooks, we did not come across any identical research topic which is the purpose of this paper.

However, in many books and papers the importance of accurate positioning of the machine on its foundations is emphasized, as well as the need of a regular check and correction of the geometric parameters and their correlations.

Korotkov (1986) points out that unchecked fitting of the machines causes imprecise sawing of the logs. He points out that the log bandsaw is the most delicate one, as it contains two sets of parts, the movable part and the machine itself, sets of elements which function separately and are physically disconnected. It is fundamentally important, according to him, that the structure is solid and in one unit.

In his papers, Klincharov (1978, 1990) mentions that before starting the experimental researches, the geometrical position between the bandsaw and its cart must be checked. If not, chances are big to get wrong measurements and results.

Rabadziski (1991) emphasizes the importance of accuracy of the samples' dimensions. Bigger dimension of the thickness than the nominal one creates a waste of wood pulp. Differences in the thicknesses of one sample cause differences in the thickness of the next one.

Filipov G., Genchev G., Savov P., Sabevski D., Jordanov N., (1983) stress the importance of the right angles, particularly of the desk and the mete. They pay special attention to the wearing of the desk which can cause change in the wood geometry. The undesirable but common bumps on the base can cause deformations that directly affect the dimensions of the object treated.

Zubcevic (1965) points out that regarding precision and consistency of the treatment, the thickness of the sawn wood is of crucial importance for getting good quality products in the final manufacture.

While analyzing the vibrations and the lateral displacement of the bandsaw, Trposki (1993) comes to a conclusion that the stronger unsymmetric vibrations and unilateral displacement of the saw are most commonly a result of bad preparation of the cutting tool, the tangential cutting of the rings or the no-longer-parallel line of the cart with the saw. Increasing the width of the cuttings for just 0,1mm reduces the usage of the raw material by 0.3%. He presents it with a value; for 160.000 m^3 treated logs, the losses would be around 600 m^3 wood.

4. WORKING METHOD

In this chapter we will analyze the origin and selection of the raw material, the way and mode of sawing, measurement, the measuring tools and the methods used for a statistic data processing.

The logs originate from the mountain of Ograzhden growing in different sites, with different quality, with length of 4.0 m, width of 10.0 cm and with different diameter. Type of wood: beech. Sawing is performed with a log bandsaw (D = 1100 mm) in manufacturing conditions. Attention is specifically paid to the thick plank stumps from each log when turning the log for 180° in relation to the starting cuts.

We measured the thickness of every thick plank stump with a digital caliber, right or down (d_1) and left or up (d_2). 20 measurements were made along the length of the thick plank with a total of 40 measurements. (Figure 1).

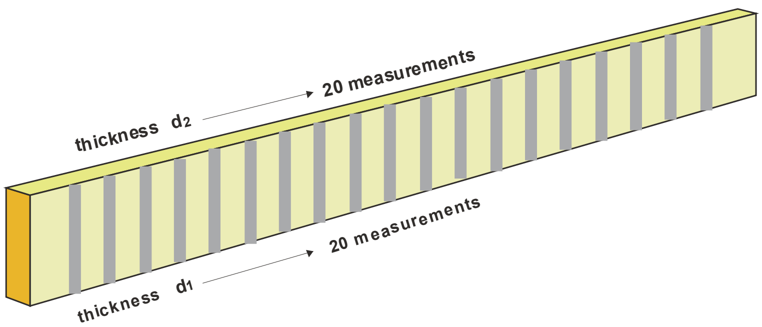

Figure.1. *Thickness measuring points (zones)*

5. RESULTS OF THE RESEARCH

The thick plank stump of the first log (D_{sr}=33cm) is with width of 19 cm, with log volume of (V_1=0,342 m^3) and thick plank volume of (V_2=0,0418 m^3). The thick plank share, in percentage, in relation to the log, is 12.22%. This datum is important because of the significance of the loss for future class reduction.

The values of thickness measurement of the thick plank (d_1) are measurements taken on the bottom side of the plank (while it is placed on the log), i.e. from the right side of the thick plank (when it is placed on the roller dolly). Measurements indicate drop in the thickness from 55.5 to 53.4 mm, i.e. the difference in thickness along the right side of the thick plank is 2.1mm.

The values of thickness measurements of the thick plank (d_2) are measurements taken on the upper side of the plank (while it is placed on the log), i.e. from the left side of the thick plank (when it is placed on the roller dolly). Measurements show reduction of thickness from 53.2 to 51.6 mm, i.e. the difference in thickness along the left side of the thick plank is 1.6 mm.

The difference in thickness values, taken diagonally, is 3.9 mm.

The mean value of the measurements of thickness d_1 is 54.36 ± 0.15 mm, standard deviation is 0.65mm and the variation quotient is 1.20%.

The mean value of the measurements of thickness d_2 is 52.62 ± 0.12 mm, standard deviation is 0,54mm and the variation quotient is 1.03%.

The difference between the analyzed groups of measurements (d_1 and d_2), i.e. the t-test, is of great significance, with value of 9.18.

The trend of measurements (Figure 2), according to the regressive analysis, best follows the equation of a straight line. High correlation quotients (for d_1, R^2=0.8837 and for d_2, R^2=0.9074) clearly determine the almost entire and positive dependence on the measurements.

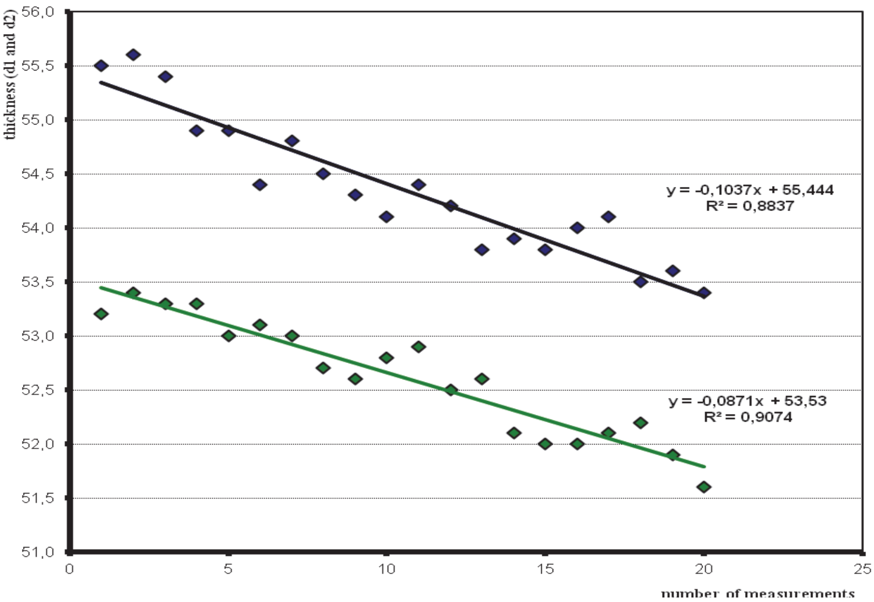

Figure 2. *Trend of measurements of last board, width 19 cm (first log beech)*

Because of the extensiveness and similarity of measurements, the results on the other nine logs will not be presented, but they will be included in the discussion and in the results.

6. DISCUSSION

The data was gathered in a working environment, without any particular restrictions. The diameter of the logs and the widths of the last planks were taken as they came.

All measurements point to the fact that there is a considerable correlation between them, but there is still a large significance in the pairs analyzed. Observed from both directions, the drop in thickness is apparent.

The first inspection was done across the length of both sides of the plank. The difference in thickness in both tree species, regardless the sawing disposition, was approximately 2.0 mm per length of 4 m. The required thickness of the plank of 55.0 mm, was at the end of the cut, which indicated that the positioning device for the vertical carriers was mounted on the next-to-last or last carrier. Reason for this is the excessive wear of the coil-like spindles in the last two carriers. As a consequence, the thickness across the length of the plank differs. This drawback can be eliminated by replacing the worn parts. Figure 3 shows a cross section of the cart along with its four carriers. The back carriers deviate by 2 mm in relation to the moving trajectory of the front carriers.

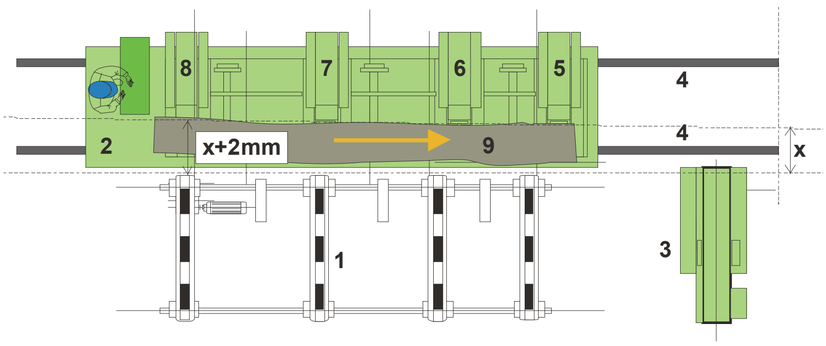

Figure 3. *Deviation of back vertical carriers, in relation to front ones, in a log bandsaw cart: 1-heavy perpendicular chain-like conveyor, 2-cart, 3-main machine, 4-rails, 5 and 6-front vertical carriers, 7 and 8-back vertical carriers, 9-log*

The second inspection was done perpendicular to the length of the plank from its both sides. The deviation of 2.0 mm at a width of 30 mm was evident. The reason for this anomaly was the wear of the prismatic parts of the rail and the cart wheels. They are positioned on the side closer to the saw (Figure 4). The opposite side of the rail and the wheels are flat. The flat wheels feature only rolling friction, but the prismatic parts, beside the rolling friction, also feature sliding friction in the contact area. This is the reason why they suffer larger wear and tear over time, compared to the cylindrical wheels. Measuring horizontality of the base surface of the cart showed that there was a great deviation in horizontality, of 5.8 mm on the side of the prismatic rail in comparison to the side of the flat rail. This downside can be corrected if the diameter of the flat wheels is reduced by 11.6 mm, or if they are replaced.

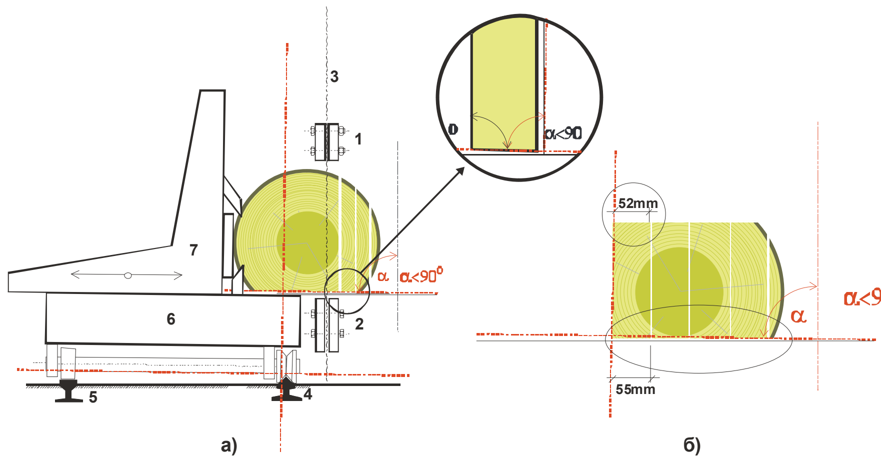

Figure 4. *Deviation in horizontality of the working surface of the cart as a result of wear and tear of the prismatic wheels and the rail: a) horizontal and vertical deviation; 1-upper rudder, 2-lower rudder, 3-cutting device (band saw), 4-groove for the prismatic wheels, 5-groove for the cylindrical wheels, 6-pulley (cart) for the log; b) deviation in the dimensions of the last plank*

As a result of the crisscross geometrical anomaly, the deviation in the diagonal thickness of the planks is intolerable. It measures about 4.5 mm in planks thick between 20 to 25 cm.

The last wooden planks obtained from both types of wooden logs have degraded and below-class thickness. Their percentage share in the volume of the log ranges from 6 to 16%, depending on the mean value of the diameter of the log and the width of the plank. These planks can only be marketed as degraded and below-class lumber. The loss is sizeable.

7. CONCLUSIONS AND RECOMMENDATIONS

Based on the previous analysis, we can draw the following **conclusions**:

- deviation in thickness dimensions across the length of both sides of the plank in both wood types, regardless their sawing disposition, is approximately 2.0 mm for a 4 m-long plank.
- deviation in thickness perpendicularly to the plank on its both sides with both wood types measures 2,0 mm for a width of 30 cm.
- deviation in thickness in the diagonal cross section of the plank is intolerably high and measures 4,5mm, with a plank wide 20 – 25 cm.
- the share of the degraded planks, by their thickness, in the log volume amounts 6-16%.
- wear and tear of the coil-like spindles in the cart vertical carriers is about 2 mm.
- deviation in horizontality on the cart base surface is 5,8mm. on the side of the prismatic rail.

These conclusions show noticeable deviations which have a negative effect on the sawmill operation. Observance of the following **recommendations** can fully solve the dimensions problem of the last planks sawn from the logs, which are as follows:

- on a daily basis, before and after operation, the machine's movable parts must be cleaned and visually checked, and if necessary, the machine must be lubricated.
- at least once a week the geometrical relations must be measured applying always the same reference points, and the data must be recorded in a table.
- once a year, (when working in two shifts), the worn parts must be replaced or repaired, in this case they are the coil-like spindles for positioning of the vertical carriers.
- once in every two years the cart cylindrical wheels must be treated, so that its base surface should be 0,5 mm lower at the side of the cylindrical wheels.

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BUILT IN AND FREESTANDING FURNITURE IN A TRADITIONAL MACEDONIAN HOUSE FROM THE 19TH CENTURY

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ABSTRACT

Macedonian experience in interior and furniture design in the 19th century features authenticity and constant development. They have developed in a successive manner, starting from the richly structured local and ornamental examples of interior with incorporation of style developed models taken from the western architecture and the Mediterranean, and eventually implementing these experiences into recognizable local interior and furniture design expressions. The building renaissance enthusiasm in Macedonia starts its upward development during the first decade of the 19th century. The enthusiasm can be perceived through a large number of authentic buildings, interiors and furniture designs that involved Macedonian construction teams who were famous in Macedonia's neighbouring countries, too.

Taking into consideration the importance of the research methods in interior and furniture design background, the process of discovering the unknown aspects of this specific development leads to conclusions about existence of two centuries of specific history and traditions. Most significantly, discovering different processes of style transformations in all types of architecture and interior design, remarkably speaks about local adaptations and powerful individuality of some of the masters from the period of the 19th century.

Key words: tradition, continuity, freestanding and built in furniture, contemporary design, interior

1. INTRODUCTION

Based on an effort made to reconstruct the condition with the interior and furniture in a Macedonian house of the 19th century, we can see that the inside decoration, the design of the interior elements, built in as well as freestanding furniture, play a significant role in people's daily lives from that period. Beside carefully chosen architecture of the building and its fitting into the scenery, the interior and furniture were mandatory and were treated with the same attention and care. Figures 1 and 2.

Tradition was preserved by creating furniture and objects for personal needs; their design, once adopted and acknowledged, was handed down from generation to generation. Analyzing them nowadays, we are still fascinated by their simplicity and beauty, as if they were made from elements taken from the universe, woven by human thoughts and hands.

The simple technique of manufacture was a result not only of the familiarity with the manufacture process, but also the desire to emphasize its functionality. Thus, various types of furniture, objects and household facilities were created – from the simplest ones originating from nature itself, to more complex ones which were reflection of the specific region and time when they were made. Their value was not only functional or aesthetic, their presence in the home was a set of signs which reflected the features of that time, the people and the host who used them, beginning with the ethnic group, the social status, or the region where the object was used. The design of freestanding furniture is not accidental, nor is it a product only of a person's creativity and talent. This is proved by researches which have tracked the existence of the same motives far in the past, reaching prehistoric period. These facts lead to the conclusion that furniture with its ancient design has existed and developed as a matrix, following predefined routes determined by habits, tradition and a genetic code specific for our people.

2. PROPORTIONAL AND ANTROPOMETRIC DIMENSIONING

The basic element of structuring and designing freestanding furniture was the principle of following proportions. Good proportions are obvious in chairs, trunks and cases, but even when they were not a result of a previously thought-out analysis, when were manufactured in primordial times, they contained that special feeling of proportion. This aspect is a result of the anthropomorphous dimensioning of every furniture manufactured for the Macedonian house in the 19th century.

Based on all analyses related to anthropomorphous measurements of freestanding and built in furniture, we can conclude that when furniture was structured, designed and manufactured in reformed Macedonian house, there was an utter modular and proportional compatibility of all the elements.

Anthropomorphous and ergonomic proportions of freestanding and built in furniture reveal the interaction between the units and the whole, as well as among the units themselves. Applying anthropomorphous modulus expressed in cubits (1ARM) which is also a proportion unit, three demands of the interior can be established: functional, technical and aesthetic one.

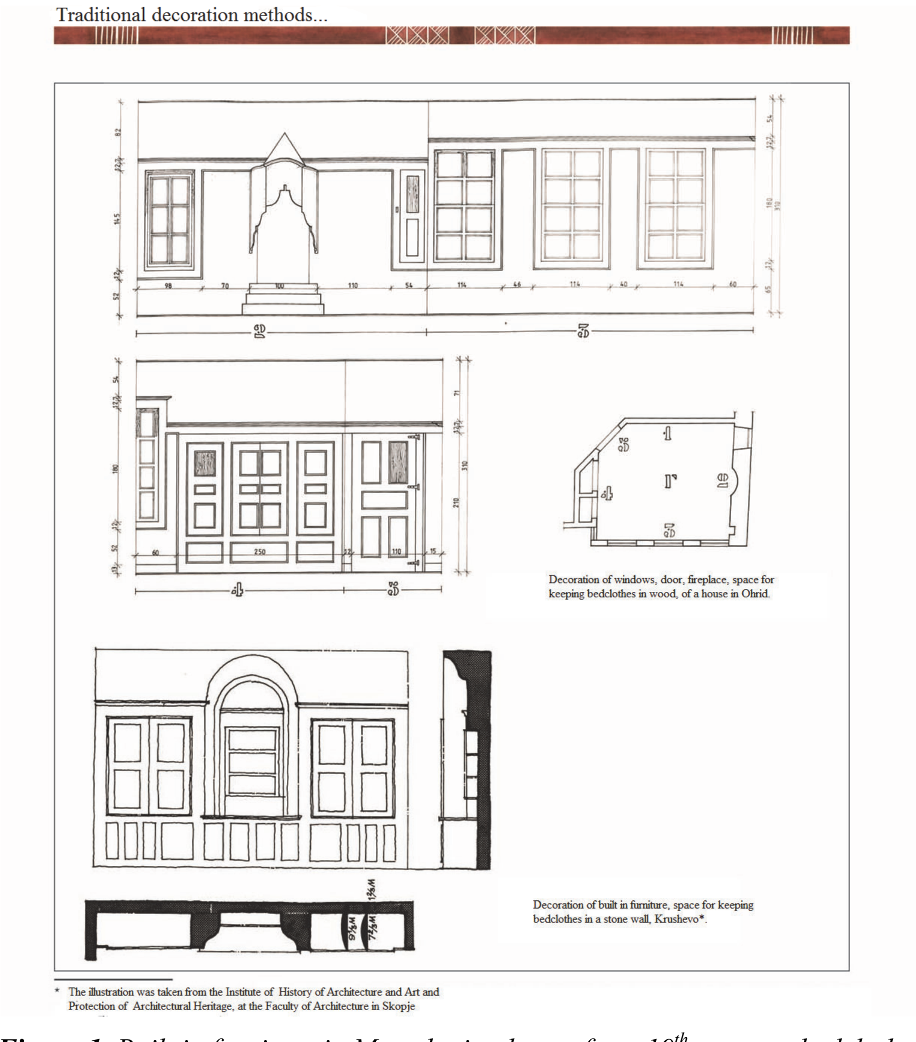

Figure 1. *Built in furniture in Macedonian house from 19th century, bedclothes trunk in a wall made of wood, and bedclothes trunk in a wall made of stone, Ohrid and Krushevo.*

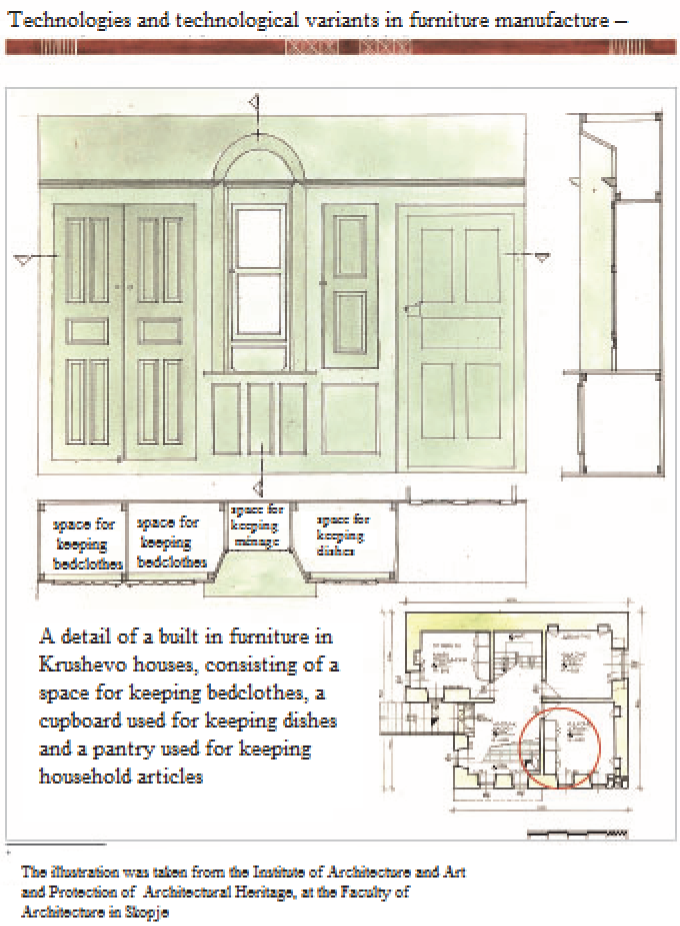

Figure 2. *Built in furniture in wall made of wood, in a Macedonian house from 19th century which includes a bedclothes trunk, a dishes cupboard and a household articles trunk, in Krushevo.*

3. DECORATION DERIVED FROM FUNCTIONALITY

Built in and freestanding furniture in Macedonian house reflecrt a specific sense of decoration, derived from functionality. Built in wooden elements such as attics, pantries, doors and the like, with their artistic contents, technical treatment and material, are major elements in the interior of Macedonian houses from that time.. Attics and pantries take up a great deal of the space, thus prevailing in the interior from roon coverage aspect, too. . The self-taught builder had felt the power of the interior language and had taken advantage of what built in furniture and the other items offered, creating harmony of all the interior components. Figure 3.

Furniture was generally made of wood, since wood was the basic building material for housing structures. Most frequently used were those wood types easily found in the environment (oak tree, chestnut tree, pinewood, beech tree, fruit trees), for which folk master carpenters, wood carvers, joiners had perfected excellent techniques for wood preparation, especially for its impregnation and preservation. In spite of the simplicity of the tools for furniture manufacture and wood treatment, these masters had achieved good results and had made good quality products.

Particularly strong feature of Macedonians' freestanding and built in furniture was its decoration. It was characterized with a variety of actions related to treatment and decoration of internal surfaces. High achievements in the field of arranging decorative elements, based primarily on the soundness of the project for built in household articles, the sense of natural forms and choice of always authentic motives, put the interiors of Macedonian houses from the past in the category of National heritage.

Figure 3. *Wooden chair, handmade, beginning of the 19th century. Museum of the city of Bitola*

Methodologically there is abundance of decorating actions, beginning from the simplest shepherd's woodcarving based on mere carving, moving to shallow, hemstitched woodcarving considered top decoration techniques, finishing with painting and moulding freestanding furniture and some segments of the built in furniture with colours, materials and motives which deserve special attention. Figure 3.

Figure 4. *A trunk with a characteristic carved decoration, ancient context, massive wood, handmade, from the 19th century, Kratovo*

Symbolic decoration of freestanding and built in furniture is a process of expression of internal, spiritual world, with the external, earthly world. Analysis of the decoration semantics and self-educated master's need to express himself by drawing, engraving or woodcarving furniture, bring us to the existence of conscious people's need to decorate their surroundings. In certain situations even the way of handmade furniture designing is related to the same expression. By short differentiation between ancient and Christian context, because those are the two ways of expression of the people in this region living at the time in question, it is obvious that they had undoubtedly left their imprint in freestanding and built in furniture in Macedonia in 19th century. Decoration process had always started with the three-dimensional geometric projections of cosmic space and shape, as they are the basic images that people unconsciously always reuse via furniture decoration.

4. TRADITION AND MODERNITY

Tradition and modernity will be considered and commented as long as history exists. One day the world might become a global village, but even in such a world man will not be able to live without memory. Nowadays a trendy designer is obliged to observe contemporary movements, but with a full respect for everything historically valuable. It is that observance that puts the designer in a situation different from that one when he is allowed to create freed from historic factors. Historic factors are not important by themselves, or because of the seriousness of the styles from the passed epochs, but primarily due to the impact they make on the ultimate users' collective memory – on the people, purchasers of the furniture designed for them and in conformity with their needs and demands.

It is the matter of an attitude with very clear views, without overestimation in one or another direction. The paths traced by the designer are based on scientific expertise about tradition, translated in the language of contemporary design theory, with permanent awareness of the technologic achievements. Any compromises following the line of the least resistance lead to easier-said-than-done solutions. Figure 5.

Figure 5. *Carved decoration with semantic meaning, antique context, trunk made of massive wood, handmade, from 19th century, Kratovo*

Analysis of the designing process in contemporary conditions leads to a conclusion that the process looses its linearity and becomes a complex activity, developing closer to the strategy. The new designing process obtains ability to learn from the variety of events which take place in an environment not completely stable and static, because the rules keep changing. Under such circumstances, the world of technology resembles contemporary expression of human imagination capacity, looks like his ingenuity, supported with his scientific achievements. Thus technology became a field where the relationship between science and technique changed. Technique development was closely connected with the development of the basically rudimentary knowledge of manual treatment of furniture.

In order to face this growing complexity, the designer has to have a transversal background, i.e. origin. Thus he can study the horizontally different specific situations, still being open for vertical recognition of the same situations, without abstracting or affecting his creativity in the process. That is why he has to be familiar with productive engineering, because it means paying attention to circularity that exists between the processes of creating and thinking. Creation means experience, and this is time of acceptance and recognition of obligations and limits which the designer needs to know if he wants to be able to create a valuable idea.

It is interesting and yet hard to validate the transformation of former interiors into contemporary ones, as well as former furniture designs into their modern counterparts. At the beginning of our century developed, capitalism in Eastern Europe had to make concessions for the proletariat, and residential premises were in the focus of social interest.

Tradition of renaissance or classicist palaces, with its experience related to this issue, helped a little the eastern architect. These structures were fossil-like, over-dimensioned and expensive representatives but uncomfortable to live in. So, these buildings were inhuman and beyond actual human measures.

In search for solution of the problem "housing for everyone", European architects spotted Macedonian house, among many others. Following Macedonian example, they made an economical apartment with built in furniture, "forgetting" to mention the sources of their inspiration, with some exceptions. Even nowadays we use built in wardrobes in our interiors, so called batteries, as well as kitchen elements, but now they come as imported discoveries of modern eastern architecture, because we were previously blind for the examples from our country existing as early as in the 9^{th} century. As always, copyright is hard to obtain, once neglected.

Culture and art are made of subtle spiritual components where the best creators' thoughts and feelings are embedded. They are dynamic signs of existence expressed in super-diving and continuity. Tradition is an essential segment of our existence. By its union with the contemporary, national recognition, identity and affirmation are reached. Because, even if the world unites ideologically and economically, which is the ultimate goal of some super-optimistic vision, the ethnos will have to keep its varied cultural identity.

In the initial stage, modern furniture design proclaimed international style, which was derived from familiar technological principles of furniture manufacture. But it was quickly recognized that there is nothing like international furniture design, that nations with their history and tradition in art actually express their distinctions. As late as after World War II, modern design theoreticians identified the term "national school". Japanese and Scandinavian designs were marked as national and regional, exactly because they reflected their traditions. After 1960s the world of design was flooded with American styling. Design and interior expression was to be a false flare and a consumers' advertisement. High economic standard once again neglected high quality state of mind.

Furniture and interior design is like a mirror with merciless objectivity. No matter how much economically imposed and ideologically forced, once it enters history, it is incorruptible and untouchable for forgery, since it also becomes an objective witness of social conditions. Regardless current oscillations in the sphere of material production (effectuated through consumers' psychology) and in the products of spiritual culture (pap, turbo-folk songs, kitsch) it is obvious that their mutual balance is main prerequisite for further survival of humans. Concerning furniture design, it means state-of-the-art international techniques and technologies reproduced in artistic expression of contemporary design, whish at the same time includes the elements of ethnic tradition, too. Therefore it is important to understand the need of and relation towards furniture (freestanding and built in), as well as in general towards the interior of Macedonian reformed house. Only by true understanding of this complex relationship, can we create our own relation to tradition, which we obviously lack.

5. CONCLUSION

Since our country is in a transitional period, we have lost our quality relation to tradition somewhere on the way of self-cognition and self-positioning in contemporary global frames. It is important to understand that relation towards tradition should not be contradictive. Tradition should be embedded deeply inside humans' thoughts and their life style; consequently, it should play a constituent subtle part of contemporary interiors and furniture design. Tradition should not be glorified at any cost, as done in some countries from Eastern Europe, but should be respected and taken with us in the global future, always shifting it in more and more contemporary frames of existence.

Macedonian reformed interiors could teach us a lot, especially how to build a national authentic style and culture. These interiors and furniture are epitome of the definition for "style" which is

defined as – a set of features which for a shorter or longer period of time mark a historical period in interiors and other segments of culture and art. Our interiors show union between freestanding and built in furniture, as well as between interior and architecture of the structure. If so, then they are representatives of our authentic regional style. An additional proof that takes us to this direction is the wide range of interiors in various regions of ethnic Macedonia from the 19th century. In spite of different climatic, landscape and social factors, these interiors still carry in their matrix a unique expression which underlies the authentic elements to follow.
Authentic style of interiors of Macedonian reformed houses is easily recognizable, as we find ourselves in it. Looking at our ethnic objects and furniture, we consider them as ours exactly because of the moment of recognition behind which there is a long tradition of forms and materials familiar to us, which we have seen and experienced, even when doing that unconsciously. We can conclude that designing furniture and interior which rely on this spiritual and aesthetic component, we are closer to the goal, which is designing furniture that will be an answer to the subtlest wishes and most concrete function-related requirements of people.

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RELATIONSHIP BETWEEN ROUGHNESS OF THE SURFACE BEING SAWN AND BLADE TEETH WEAR AND TEAR IN LOG BANDSAWS

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ABSTRACT

The subject of this paper is wear of tools as a function of active operation time, expressed through surface roughness in bandsaws, in order to determine the maximum operation time of the tool (the bandsaw) and to obtain optimum quality and quantity when sawing beech logs.

Due to the inability to continuously measure the rounding-off radius of the bandsaw teeth, wear of the tools was treated as a function of the operation time of the band saw in relation to the roughness of the surface.

Measurements were performed on beech wood specimens from the same growing location and with distinct radial cuts, to avoid the influence of the layout of the rings.

Roughness of the surface was measured with a comparator.

The results obtained from measurements suggest proportional dependence, i.e. the longer the operation time of the tools is, the rougher the surface being sawn gets.

Key words: wood, bandsaw, wear of teeth, roughness

1. INTRODUCTION

Log bandsaws have been subject of many studies aimed at finding ways to improve their qualitative and quantitative exploitation, which positively affects the choice of options when problems occur during sawing.

The accuracy of the samples' dimensions depends most on the operation manner, i.e. on the stability of the sawing equipment – the bandsaw. It is verry common to pay little attention to the blade teeth's wear, which is the most common reason for increase in roughness of the surface being sawn, the power consumption of the main and the auxiliary electric motor, bandsaw straining, change in the sawing trajectory, etc., which has a negative effect on quality and quantity of the logs processed.

On the other hand, the wear of the blade cutting teeth of the saw decreases the ease in sawing the wood fibers. The initial sharpness of the cutting teeth at the begining of the sawing process lasts for a very short time. After this period, the cutting teeth maintain a so called working shapness. Ultimately, the sawing teeth wear extremely, a situation that should always be avoided.

2. THE OBJECTIVE OF THIS RESEARCH

There are many factors that influence the sawing resistance, i.e. the sawing strength: the wood type, or, in other words, its density and toughness, the wood humidity and temperature, the sawing direction with respect to the wood fibers, the friction between the bandsaw blade and the wood, the vibrations of the bandsaw, the thickness of the pieces sawn, the thickness of the swarf/chips; the sawing speed; the roughness of the surface being sawn etc. Some of these factors have been intensely studied, but for many wood types there is no research data, and in many cases the research data is contradictory, which signifies the distinctness of wood.

The objective of this study is to prove the correlation between the roughness of the surface being sawn and the wearing of the equipment, which depends on the number of working hours of the sawing equipment, in this case the bandsaw, while sawing beech logs.

3. RESEARCH TO DATE

According to Zubcevic (1965), the ammount of sawing resistance depends primarily on the mechanical properties, the wood structure and humidity content, the geometric shape of the equipment, the type of processing, i.e. the relative direction of the sawing force with regard to the wood fibers direction, the shape and size of the sawdust’s radial cros-section, and to a smaller extent, on the cutting speed, the wear of the blade, etc.

Breznjak and Moen (1972) have reached the following conclusions: the increase in vibration of the sawing tools during the woodsawing process increases the loss of volume in the wood and power consumption. The ammount of vibration in the sawing tool is directly dependent on its sharpness or wear. The increase in power consumption is nearly proportional to the increase in the vibration, i.e. the increase of the incision width, which is in correlation with the blade wear and tear. Power consumption is directly proportional to the equipment blade bluntness. The tool bluntness leads to increment in the lateral vibrations, which also depend on: the distance between the rudder and the point where the cutting teeth enter the wood, the movement speed of the object that is being processed (wood), the spacing between the rudders, etc.

Allen (1973) maintains that more or less all of the woodsawing factors influence the roughness of the surface being sawn and the power consumption. Thus, proper layout of the blade teeth is of great significance and it drastically affects other parameters such as blade wear and tear, power consumption, vibration and lateral displacement of the bandsaw, and the bandsaw stability.

The sawing dynamics greatly influences the woodsawing resistance. It is of great importance for scientific research on the relation between vibration and woodsawing forces, the sawing speeds relation, power consumption, wood sawing accuracy, etc. Sugihara (1953) experimentally proved that the perpendicular woodsawing force increases linearly with the increase of the moving speed, i.e. the wood sawing mode.

While testing two wood types (beech and pine), Trpeski (2006) concluded that the vibration of the saw proportinally increases with increment in:

- the shifing of the object that is being processed, while maintaining constant wood sawing height and active working hours,
- the sawing height, while maintaining constant shift and active working hours,
- the active working hours, while maintaining constant shift and wood sawing height,
- controling the equipment’s vibration, which is easily achieved if an optimal (proper) shift is chosen.

Additionally, in accordance with the results, the author presents nomograms that can be used to determine the most apropriate wood sawing mode, for a given wood sawing height and active working hours of the equipment.

Many authors have studied the effect of the shift size on different wood sawing factors.

Mote (1975) performed an aproximate analyses indicated by acceleration and deceleration of the shift as destabilizing processes. The practical significance of this phenomenon is of little significance in the case of log bandsaw.

With his tests Trposki concluded that:

- increment in the shifing speed increases the roughness of the surface being sawn and vice versa;
- rise in the working hours of the bandsaw, due to increment in the tension on the back side of the blade teeth, leads to an unequal thickness of the samples. The reason stated by him is lateral destabilization of the saw;
- increase in shifting speed of the sample being sawn increases the power consumption of the main and auxiliary electric motor, owing to rise in the sawing forces;

- increment in active working hours of the equipment, due to its wear and tear, increases the roughness and high fibre content of the surface being sawn.

4. SUBJECT OF RESEARCH

The trials were conducted on a “LUIS BRENTA” – 1600 bandsaw, which has the following technical properties:

Table 1 *Technical properties of “LUIS BRENTA” bandsaw*

maximal diameter of the logs	1150 mm
wheels diameter	1400 mm
maximal length of the logs	8 m
cart opening	1250 mm
shifting speed	0-50 m^{-1}
conveyor belt speed	30 ms^{-1}
conveyor belt dimensions	1,47 x 180 x 9650 mm
power consumption of the electric motor	50 kW

Table 2. *Angular parameters of the equipment*

Saw dimensions (mm)	Step of the blade teeth (mm)	Height of the blade teeth (mm)	Angular parameters of the blade teeth				Roundness of the curve R (mm)	Sawing teeth profile (mm)	Flattening of the sawing teeth □ (mm)
			α	β	γ	δ			
1,47x180x9650	45	15	12°	54°	24°	66°	5	PV	0,45

All of the phases, from the starting point – flattening, to the end point – sharpening, were conducted under surveillance, within the limits of all practical and theoretical knowledge.

5. WORKING METHOD

5.1 Origin and choice of materials

When choosing wood type, we opted for beech – FAGUS SILVATICA, because of its economic importance, as well as the fact that it is the most common wood type processed in the sawmills in the Republic of Macedonia (out of all non coniferous trees, beech wood makes more than 70%).

The humidity of the logs sawn was within the ordinary limits for sawing in a sawmill (ranging from 48% to 57%). An electric humidity meter with accuracy of 0.5% was used to measure the humidity.

5.2 Sawing manner

The logs were sawn “with sharp blade teeth”, and for the measurement purposes, three planks from the middle of each log (Figure. 1) were taken.

The first log was sawn immediately after placing the bandsaw, the second one after half an hour, the third one after an hour, the fourth one after 1,5 hours and the fifth one after two hours. In this way the measurements were separated into equal time intervals, which allowed us to easily identify any changes in roughness of the surface being sawn. In-between the time intervals, logs were sawn for the needs of the sawmill, taking into consideration and measuring the active working hours of the bandsaw.

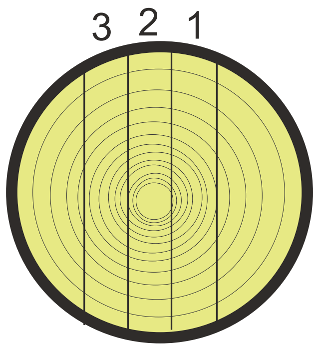


Figure 1. *Sawing manner of the logs*

The test duration was decided to be two hours, because according to a majority of authors, the optimum working time for changing the log bandsaw is two hours (the time calculated is non-stop sawing duration, excluding the preparation time). After two hours active operation of the equipment, there is an enormous increase in sawing resistance, which results into bad quality of the surface being sawn, rise in power consumption, variations in thickness, and even failure of the equipment is possible.

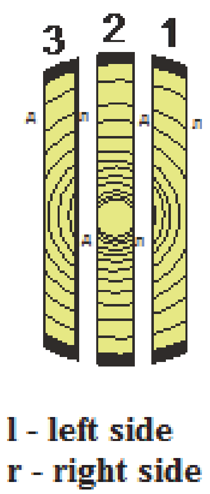
5.3 Sawing mode

Sawing mode is the relation between the kinematic factors. Main kinematic factors are the main speed (the speed of the tool/equipment), and the auxiliary speed (the logs shifting speed), and their values reflect the movement itself. Coupled, these two values represent the sawing kinematics.

With log bandsaw "Luis Brenta" - 1400, the main speed (of the tool) is constant and amounts 31 m/s(ms^{-1}). The auxiliary speed (logs shifting speed) alters constantly from 0-50 m/min. In our measurements performed with a chronometer, the logs shifting speed while sawing the middle planks in identical time intervals was constant and it was 10 m/min. The shifting speed in-between the intervals was optional, depending on the equipment capacity and the operator's judgement.

5.4 Way of measuring and measuring gauges

From each of the selected five logs (with approxiamately identical quality and dimensions), 3 (three) planks from the middle were sawn at each half an hour of active working time. For each plank, from its left and right side (in the sawing direction), ten measurements of the roughness of the surface being sawn were taken. In that process, we avoided the measuring points which gave extreme values due to various sorts of imperfection of the wood.



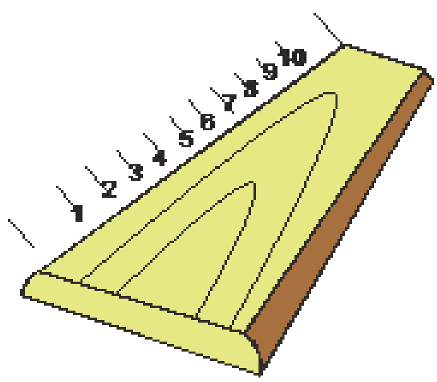


Figure 2. *Three planks from the middle* ***Figure 3.*** *Roughness measuring points*

Since the input values are different, it is normal to expect difference in the output values. It is common, as wood is an anisotropic matter, which results into slight variation in the results obtained. The gauge used for measuring straining of the main electric motor was an analogous amperemeter, with readings from 1-150 A (ampere). The results were read directly on the analogous amperemeter.

Roughness measurements were taken as follows: firstly 25 cm. were deducted from the ends of the planks, in order to get conformity with the sawing speed. Afterwards, at each 40 cm., choosing good flawless surface, at spots with highest depth (as per the criterion R_{max}), by means of a comparator, the dimensions of roughness were taken. For each half an hour active workinng time we made 60 measurements, a total of 300 measurements.

The reference length, which is actually the length of the measuring device flange, measures 80 mm, and the roughness of the tip of the measuring needle measures 0,25 mm, with accuracy of readings of the measuring instrument being 0,001 mm. Measurements were taken from perfect surface points, and the values obtained were put into tables separately for each surface being sawn.

6. RESULTS AND DISCUSSION

6.1 Roughness of the surface being sawn, after active working time of 0 hours

(at the beginning of sawing)

Mean roughness value of the surface being sawn, obtained after taking measurements, was 603,94 ± 2,20 µm, with standard deviation of 17,058 ± 1,557 µm and variation coefficient of 2,828 ± 0,258%.

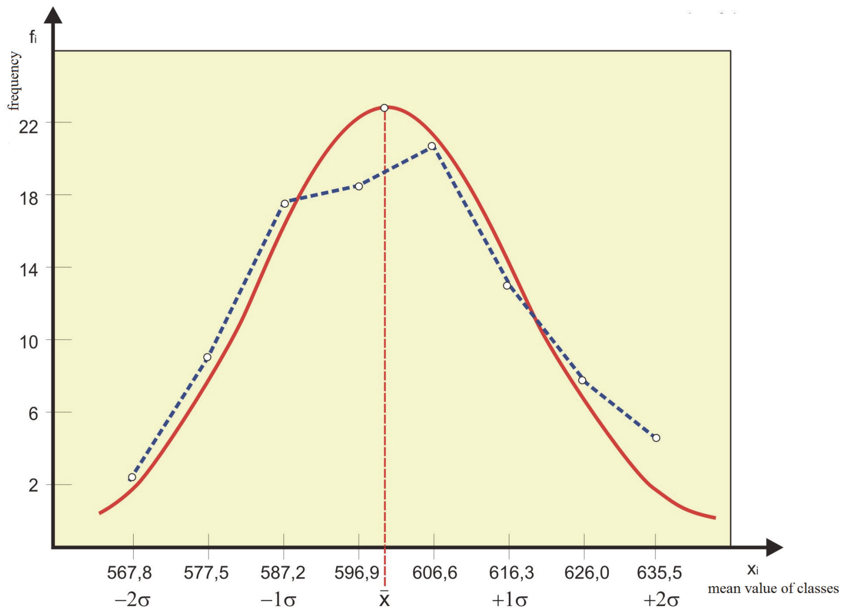


Figure 3. *Frequency range and curve of normal distribution of roughness after active working time of 0 hours (beginning of sawing)*

6.2 Roughness of the surface being sawn, after active working time of 0,5 hour

The empirical data on roughness of the surface being sawn, after active working time of half an hour, were divided into eight classes, with class range of 8,8 µm. The values obtained are presented in table 3.

Mean roughness value of the surface being sawn was 674,81,99 m, with standard deviation of 15,421,407 m and variation coefficient of 2,285±0,208%.

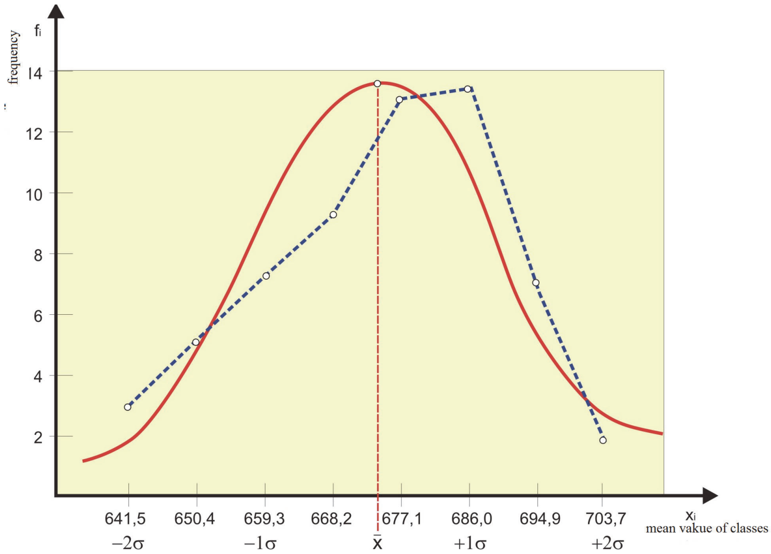


Figure 4. *Frequency range and curve of normal distribution of roughness after active working time of 0,5 hour*

6.3 Roughness of the surface being sawn, after active working time of 1,0 hour

The empirical data on roughness of the surface being sawn, after active working time of one hour, were divided into eight classes, with class range of 9,4 µm.

Mean roughness value of the surface being sawn, after active working time of one hour, was 776,66 ± 2,215 µm, with standard deviation of 17,159 ± 1,566 µm and variation coefficient of 2,206 ± 0,201%.

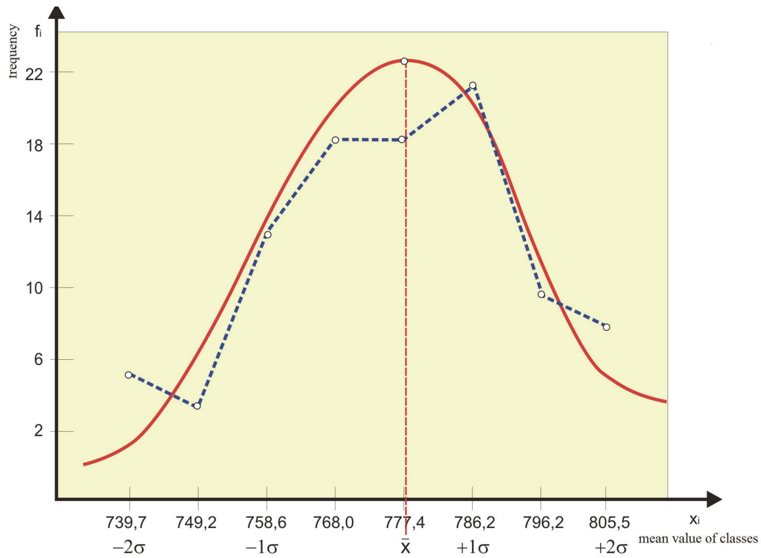


Figure 5. *Frequency range and curve of normal distribution of roughness after active working time of 1,0 hour*

6.4. Roughness of the surface being sawn after active working time of 1,5 hours

Based on the empirical values of roughness of the surface being sawn after active working time of 1,5 hours, tables 9 and 10 were drawn, with eight classes and class range of 11,5 µm.

Mean roughness value of the surface being sawn after active working time of 1,5 hours, was 926,175 ± 2,636 µm, with standard deviation of 20,424 ± 1,864 µm и variation coefficient of 2,205 ± 0,201%.

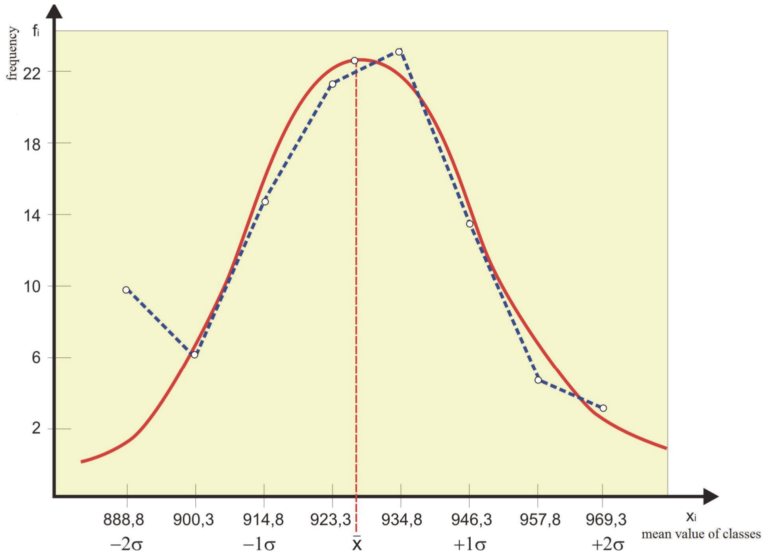


***Figure 6**. Frequency range and curve of normal roughness distribution, with active working time of 1,5 hours*

6.5. Roughness of the surface being sawn, with active working time of 2,0 hours

Based on the empirical values on raoughness of the surface being sawn, after two hours active working time, tables 11 and 12 were drawn, with eight classes and class range of 10,3 μm.

Mean roughness value of the surface being sawn, after active working time of 2 hours, was 1181,33 ± 2,593 μm, with standard deviation of 20,086 ± 1,833 μm and variation coefficient of 1,70 ± 0,155%.

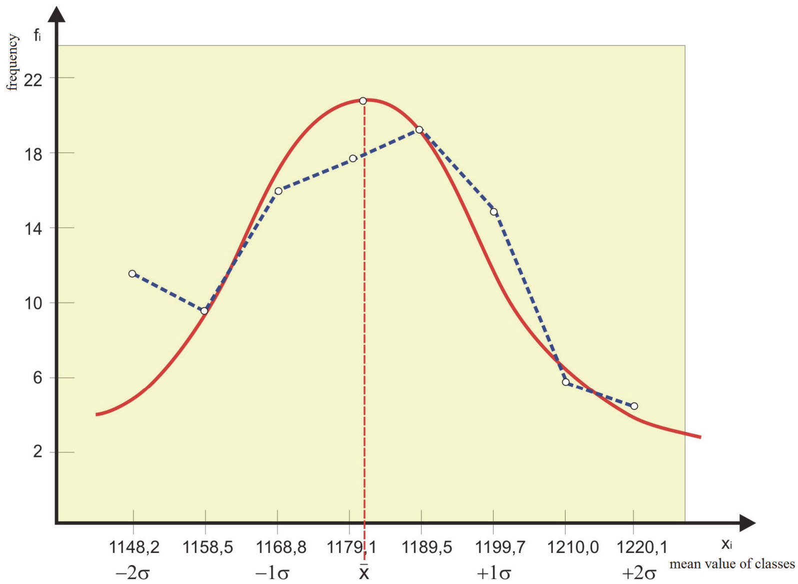


***Figure 7**. Frequency range and curve of normal roughness distribution after active working time of 2,0 hours*

6.6 Total roughness value of the surface being sawn, after active working time from 0 - 2,0 hours

Major indicator of roughness dependence on wear and tear of the bandsaw blade is the total roughness of the surfaces being sawn after active working time at the beginning (0 hours) till the end of the sawing process (after 2,0 hours).

Mean roughness values after active working time of 0, 0,5, 1,0, 1,5 and 2,0 hours are shown in table 3.

Table 3. *Mean roughness values after different active working times*

Ord. No.	Active working time (hours)	Mean roughness value [μm]
1	0,0	603,94
2	0,5	674,80
3	1,0	776,66
4	1,5	926,18
5	2,0	1181,33

For the sake of better presentation of the mean roughness values, they are also given in Figure 8.

The graph clearly shows that roughness values are dependent on the duration of active working time, i.e. roughness values do not increase proportionally but exponentially. At the very beginning of the working time, between 0 and 1,0 hour, roughness values growth is not so drastic. However, between 1,0 and 2,0 hours of active working time, roughness values increase dramatically.

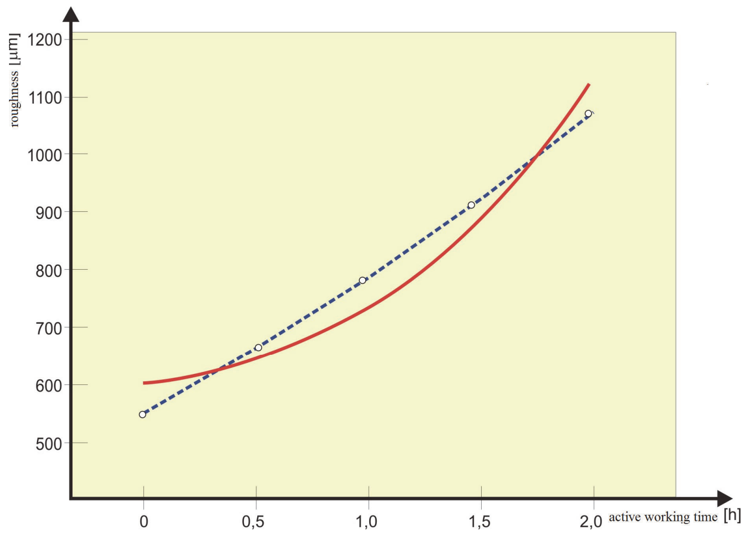


Figure 8. *Total dependence of roughness of the surfaces being sawn on the active working time, from 0 - 2,0 hours*

7. CONCLUSIONS

From the results obtained from testing dependence of roughness of the surfaces being sawn on duration of active working time, we drew the following conclusions:

1. Mean roughness value of the surface being sawn, obtained after measurements performed at the beginning of the sawing process, was 603,94μm.
2. Mean roughness value of the surface being sawn, after 0,5 hours of active working time, was 80 μm.
3. Mean roughness value of the surface being sawn, after 1,0 hours of active working time, was 776,66 μm.
4. Mean roughness value of the surface being sawn, after 1,5 hours of active working time, was 926,175 μm.
5. Mean roughness value of the surface being sawn, after 2,0 hours of active working time, was 1181,33 μm.
6. There is obvious dependence of roughness of the surface being sawn on the duration of active working time, i.e. roughness values do not increase proportionally but exponentially.

7. At the beginning of working time, i.e. between 0 and 1,0 hour, roughness values do not grow drastically and their values range between 600 to 700 μm.

8. Within active working time of 1,0 - 2,0 hours roughness values increase dramatically, reaching ranges between 700 до 1180 μm.

There is no doubt that sawing quality does not depend on active working time only, it is influenced by other factors, too, such as sawing height, physical and mechanical properties of the wood being sawn, type of wood, sawing modes and sizes of the cutting parts of the sawing devices, various kinematic factors, availability of the sawing tools and the like, all of which were not subject of this research. This is, however, indicator of the comprehensiveness of this issue and the need of additional studies and researches in this area.

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VALUE CHAIN ANALYSIS OF WOOD BASED PRODUCTS FOR PRODUCTION OF RENEWABLE ENERGY IN ALBANIA, MACEDONIA, KOSOVO AND MONTENEGRO

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ABSTRACT

All Balkan countries aspiring for the EU membership intends to increase the contribution of renewable energy derived from wood resources in the National Primary Energy consumption. Our objective was to investigate the value chain analysis of the wood based products for renewable energy production in Albania, Macedonia, Kosovo and Montenegro. More than 50 stakeholders were interviewed in all studied countries. The study was focused on the analysis of the current situation of wood fuel value chain at a regional scale beginning with raw timber supply till to the end user (consumer). At all the countries involved in this study firewood was a very important source for heating and cooking not only in rural areas but also in urban areas. The weight of firewood on national energy demands was different between countries ranging from 10% (Montenegro) to 36% (Albania). At all countries there is an urgent need to increase the value of wood, because still after timber logging in the forest remain an amount of 20-30% of harvested timber. Potentially this source could be use for chips production increasing also the role of forest sector on national level energy demands. Another important issue raised by the study was the energy efficiency which in rural areas is very low. For that reason our study indicated that each country needs to take measures to improve in private and public buildings the thermal insulation and to find ways for installing central heating systems. The present situation of the wood fuel value chain in the six regions showed that this activity is in its infancy and needs further development for the future. The further development of the wood fuel value chain will enhance the share and the contribution of forest biomass energy in the national energy balance as well as encouraging rationale usage of sawn wood and sustainable management of forests.

Key words: renewable energy, value chain, pellet, briquette, stakeholder

1. INTRODUCTION

The goal of energy security is a crucial factor for future development of every country. In order to reduce the dependence on fossil fuels and import of energy, many countries have started the programs for researching and development of renewable energy sources of energy. It's a widely known fact that burning fossil fuels, especially coal, oil and natural gas releases into atmosphere significant amounts of carbon dioxide (CO_2) and other greenhouse gases. In this regard renewable energy sources can play a significant role since they produce energy with little or no CO_2 emissions. Obvious energy requirements of Albania, Montenegro, Macedonia and Kosovo stress the importance of evaluation of the forest biomass potential for energy purposes. The most important bio energy resources in such countries are: forestry residues, fast-growing plantations, wood-processing industry residuals. There is a commitment of these countries to increase the share of renewable energy versus national energy demands. They have set ambitious targets to increase the contribution of renewable energy derived from wood resources in the total Primary Energy consumption. These countries aspiring for the EU membership, have committed the transfer of EU legislation (*Aquis Communitaire*) into their legal system.

In all these countries forest biomass plays a significant role in meeting energy demands. The role of forest biomass in total energy consumption vary among countries.

Thus in Montenegro the consumption of electrical energy for 2012 was 8333 GWh of which 30% of electricity was imported. The firewood represents the most used wood bio fuel within the wood biomass consumption in Montenegro. The total consumption of firewood in 2011 was 732 911 m^3, of which there were 96% spent by households, and the rest of 4% was spent by all other categories of consumers. The firewood was mostly used in baker's shops 1.48% and restaurants 1.23%. The target for providing energy from renewable energy sources (RES) accounts to 1330 MW for 2020, where the biomass will provide only 3 MW of the overall amount.

During year 2005 the use of RES in Macedonia accounted for 3016 GWh. In that, biomass was used as final energy in the amount of 1767 GWh and participated with 59% in the total use of RES in Macedonia. With consumption of 166 ktoe (1930 GWh), forest biomass has a significant share in the energy balance of the Republic of Macedonia. Biomass is mainly used by households and fulfils 30 – 33% of total energy needs. Around 430,000 households (76%) use biomass for heating purposes. Wood and wooden coal account for 80% of total biomass used for energy purposes. The contribution of biomass energy in 2020 is account for 3240 GWh, which represents a relative share of 21% (ECRB 2010).

Kosovo has a significant potential on renewable energy sources, which for the time being are not used. Approximately 98% of power generated within Kosovo is from two lignite coal-fired thermal power plants. Summing the total in either figure gives an estimate of the total consumption of electricity in the Kosovo grid in 2010 of 5636 GWh. Households energy demands are 534.7 toe for 2012. Human Development Report on Energy for Development (UNDP Kosovo 2007) has identified firewood as the main source of heating by 80 percent of households surveyed, with electric heating being the main source for 12 percent. There is only a small difference in the relative use of electricity and firewood between urban and rural households. Electricity is used by a greater number of urban households (16 percent) than rural households (7 percent), with a similar inverse difference in the use of firewood for heating (81 percent in urban, 88 percent in rural).

Even for Albania where over 95% of electricity and 20-23% of total primary sources are provided by hydro, use of other renewables is important because improves security of energy supply and energy sector sustainability. In Albania the energy consumption during 2012 was 7969 MWh of which 27% was used by household (Instat 2013). Forests cover about 36% of the Albanian territory and together with the pasture area the coverage is about 52%. Various surveys showed that firewood in Albania meets 36% of energy demands for heating and 12% of energy for cooking (EESDC 2008). The total firewood consumption by different sectors is estimated at 2.55 million m^3/yr (Savcor 2005). Albania has set an ambitious target to provide till to 2020 36% of energy demand by RES. All aforementioned countries except Kosovo, have signed the Energy Treaty for South East Europe which obligates that each Contracting Party provides to implement the Directive 2001/77/EC on the promotion of electricity within one year of the date of entry into force of the Treaty.

Through of a comparative analysis we have defined a clear picture of common approaches and differences that exist between each country involved in this study. This study is important for these countries because the major part of the population still live in the rural areas using the wood fuel for heating and cooking. The efficient utilization of biomass resources enhance also the contribution of forest sector and reduce the losses of timber from forest areas. In this point of view the use of alternative wood fuel products such as: chips, pellet, briquette etc will increase the burning efficiency and will provide a great amount of energy.

The objective of the study was the analysis of wood fuel value chain in all regions involved in the study and identification of practical interventions to make the wood fuel value chain functional in a sustainable manner increasing the household incomes and other actors (producers and traders) benefits.

2. MATERIAL AND METHOD

The methodology used is focused on the analysis of wood fuel value chain beginning with wood production till to the end user. The study is consisted of research based on the source of biomass as well as theoretical and practical-technical approach. The information used in this study was provided by field visits carried out in four countries (6 regions), where Netherlands Development Organization (SNV) has identified the first attempts of wood fuel production such as pellet and briquettes. The study was carried out in the regions of Elbasani and Pogradeci (Albania), Berovo (Macedonia), Bijelo-Polje (Montenegro), Mitrovica and Decani (Kosovo). Two approaches were applied for information obatining: (1) Interviews with experts of relevant fields connected with forest biomass energy; (2) assessment of the available documentation. During field work conducted from 17 September to 20 October 2011, in all above-mentioned regions were conducted face to face interviews with 58 stakeholders such as: public forest enterprise directors (6), representatives of private forest association (2), representatives of private forest logging companies (3), representatives of public education institutions (4), representatives of wood processing industry(2), representatives of wood fuel production (7), vender of wood stoves (1), household consumers at rural areas (35).

The research was accomplished based on a careful analysis of data provided from responsible institutions of forest and energy sector as well as from data provided during interviews. This analysis was focused on the evaluation of the potential raw timber at country level, current state of the wood fuel producers as well as on value chain characteristics for briquette and pellet as main wood fuel produced in the studied countries. The evaluation of the potential raw timber was done based on the data provided from responsible institutions at each country, while the value chain and current state of the wood fuel sector was elaborated based on the data provided by interviews with all stakeholders. Therefore the main focus will be on presenting: forestry biomass potential, current state of wood fuel production in all studied countries as well as the value chain of the most common wood fuels encountered during field survey.

3. RESULTS

3.1 The potential of raw timber supply

The quantification of available raw material is important for assessment of wood fuel potential production (Table 1). This evaluation gives a clear picture of the whole potential sources for providing forest biomass including firewood, sawdust and shavings (Table 2).

Table 1. *Statistics of forest resources in the studied countries*

General information	**Kosovo**	**Albania**	**Macedonia**	**Montenegro**
Total forest area (ha)	464 800	1 502 161 [1]	1 091 857	721 298
State forests (ha)	278 800	525 756	835 055	377 322
Communal forests (ha)		901 297	-	-
Private forest (ha)	185 920	75 108	94 146	243 568
Broadleaves %	66	65.3	58.5	79
Conifers %	34	34.7	41.5	21
Total standing volume (m^3)	53 000 000	73 500 000	73 300 000	70 600 000
Of state forests (m^3)	33 500 000	-	67 600 000	64 000 000
Of private forests (m^3)	19 500 000	-	5 710 000	12 400 000
Gross annual increment (m^3)	1 300 000	1 150 000	1 830 000	1 431 000
Annual allowable cut (m^3)	**900 000**	**850 000**	**1 230 000**	**832 177**
Official figures of harvested timber (m^3)	**210 000**	**2 700 000**	**752 000**	**520 000** [2]
Industrial roundwood (m^3)	23 596	444 110	142 000 [3]	218 316
Firewood (m^3)	187 667	2 300 000	583 000	301 684

Source: *Danon et al (2010); ** Nikolov N (2004);***(ANFI 2004)

[1] (ANFI 2004). Albanian National Forest Inventory
[2] Danon et al.(2010).
[3] Nikolov N(2004)

These statistics showed that each country can generate e sustainable yield ranged from 832 thousand (Kosovo) to 1.3 Million cubic meter (Albania) of fresh solid wood which is a minor part of the wood fuel consumed in the market. Other sources of wood supply like sawmills can provide a small amount of wood available for fuel production through offcuts, sawdust etc. The exact identification of wood fuel amount in the market is a difficult equation that needs detailed surveys. Results from the forest resource assessment conducted for each source of timber supply have been drawn together in order to present an overall picture of the raw material supply at regional and local level.

Table 2. *Raw timber supply from various sources for energy production at national and local level in studied countries*

Sector	Wood fuel	Albania		Macedonia		Montenegro		Kosovo	
		National level	Case study	National level	Case study	National level	Case study	National level	Case study
Forest logging	Firewood or chips	2 300 000	1 400	583 000	4 620	226 517		187 667	45 000
Sawmill									
Off-cuts	Firewood or chips	97 770	572	37 180		36 086	3 470	5 191	2 739
Sawdust	pellet or briquette	35 553	260	13 520	1 680	13 122	1 360	1 888	996
Thinnings	Firewood or chips	30 000	4 500	5 000	500	2 500		5 000	1 000
Ileggal cutting	Firewood or chips	28 400		8 000		9 000		100 000 [4]	5 000

3.2 Current state of wood fuel production

All the activities of wood fuel production were located in the districts with high amount of forest area and with a great potential for raw material supply. We noted that in Montenegro (Bijelo-Polje), Kosovo (Decan) and Macedonia (Berovo) was developed the industry of briquette production. This industry was established as a successive part of wood processing industry and the raw material was provided from off cuts and sawdust. That was the best solution because they reduce the transport cost and have a secured supply with raw material. In Albania was developed the pellet industry, but it was not part of wood processing industry. The producers have provided the raw material from wood processing companies, without being secure in the long-term supply of raw material. In order to meets the demands for raw timber the pellet producer in Elbasani has used a sieve machine for fractioning all shavings provided from sawmills. The summary data about wood fuel producers and their infrastructure are given in the Table 3.

Table 3. *Summary data of available capacity of woodfuel production in studied regions*

Woodfuel producer	Location	Woodfuel type	Production Capacity	Raw material supply	Storage facility	Nr of employee	Price of woodfuel	Product packaging	Market
MakTex	Berove/ Macedonia	briquette	200 kg/hour	Local area	indoor	2	150 euro/ton	No data	Local market
Evropa transport	Berove/ Macedonia	briquette	120 kg/hour	100 %	indoor	2	Na	10 kg	Local market
Jeta-H	Strelc/ Kosovo	briquette	350 ton/yr	60%	indoor	2	120 euro/ton	20 kg	Local market
Fa & Bio	Elbasan/ Albania	pellet	800 kg/hour	Local area	indoor	3+ 2	180 euro/ton	15 kg	Local market and public institutions
Nature energy	Pogradec/ Albania	pellet	125 kg/hour	Local area	indoor	2	130 euro/ton	15 kg	Export Italy and Macedonia
Viena-Commerc	Veleshnje /Macedonia	pellet	125 kg/hour	Local area	indoor	2	250 euro/ton	10 kg	Local market

[4] Rec et al.(2010).

3.3 Wood fuel value chains

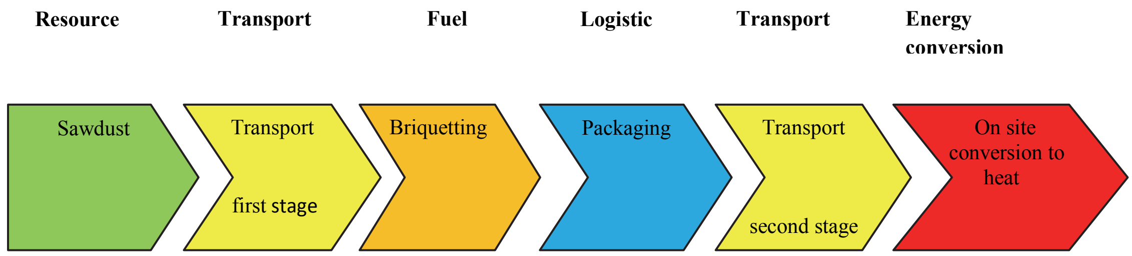
3.3.1 Briquette value chain

Briquette/ Bio-coal or white-coal is a solid fuel made from a variety of waste materials such as charcoal from low-density wood, agro-forestry waste material, domestic, municipal solid wastes and typically any type of biomass waste. Briquetting is the process which converts these low density biomass into high density and energy concentrated fuel briquettes. Briquettes have Gross Calorific Value (GCV) up to 4200 Kcal/kg. About 2.2 kg of briquettes are equivalent to 1 liter of furnace oil.

Figure 1. *Views of briquette production in the studied sites*

We noted that all briquette producers have used only dried sawdust for briquette production. They didn't have grinding machines for using slabs or other off cuts for briquette production. For that reason they were buying sawdust (40-50 euro/truck) to fulfill their demands. Shredding might be required depending on the waste being processed. The raw material (sawdust) is mixed with a film of binders usually starch to enhance adhesion and produce uniform briquettes. In case of lignin rich biomass waste, there is no need to use binders since lignin liquefies during carbonization and acts as natural binder. The briquettes usually contain about 10% of binder and about 30% of water before drying down to about 5-10 % moisture content. This mixture is then transferred into a briquettizer / molder which form uniform-sized briquettes. These are then dried and packaged. In the value chain analysis we have considered the maximal distance of 50 km for providing the raw material (sawdust) for briquette production. Based on the data of briquette producers (Macedonia and Montenegro case) the cost for sawdust purchase was 12.5 euro/ton. From their activity of wood processing they are able to provide only 60% of their demand. The cost for transport was 1 euro per 4 ton of sawdust or 0.25 cent per tonne. The cost of plastic for packaging was 10 euro/tone and the briquette producers consider it as very expensive. The value chain of briquette production is estimated based on the following scheme

Briquette value chain



Based on the upper scheme we have estimated the cost of briquette per unit weight for various segments of value chain (Table 4).

Table 4. *The price of value chain segments for briquette*

Price of the sawdust	12.5 euro/ton
Transport 1-stage (distance 50 km)	0.25 euro/km/ton or 12.5 euro/ton
Cost of briquetting	65 euro/ton
Packaging	10 euro/ton
Transport 2-stage	12.5 euro/ton
Gross benefit	37.5
Total	**150 euro**

The produced briquettes have a calorific value of 19.7 GJ/tonne and the total cost for delivered wood energy is 7.6 euro/GJ. The price of briquettes in the market ranging from 120 (Kosovo) to 150 euro per tonne (Berovo and Bijelo-Polje) and the price depends on the briquette moisture and the costs for each segment of briquette value chain.

3.3.2 Wood pellets value chain

The pellet could be produced from forest residues or directly from sawdust. To make wood pellets from forest residues requires comminuting the material to a particle size of less than one millimeter and drying to at least 15% moisture content (wet basis) prior to the press. Pellets produced from forest residues are likely to be of lower quality than wood pellets made from wood-processing residue. For example, they are likely to have higher ash content due to bark and other contaminants. These pellets could be referred to as an industrial-grade pellet. In comparison to the chains considered this chain contains much more fuel processing. This greater processing is more costly but leads to a higher-quality fuel that can reduce transport and heat plant costs. At both cases of pellet producers, identified in Elbasani and Pogradeci region, they use for pellet production the sawdust bought from wood-based industry. They provide the sawdust at e distance till to 20 km in order to reduce the impact of transport cost on the final pellet cost. In this value chain, sawdust is transported (first-stage transport) to the manufactory where it is dried firstly and then is pelletized. The pellets after production are transported (second-stage transport) to the pellet consumer. The main pellet consumers were hospitals and kindergardens especially to Elbasani area. The pellet value chain was analyzed based on the prices provided from the existing pellet producers. The scheme and the cost estimation for each segment of pellet vale chain are presented as follow:

Pellet value chain

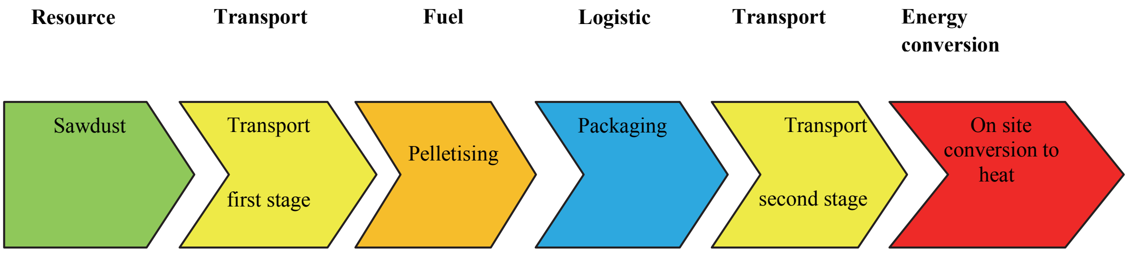


Table 5. *The price of value chain segments for pellet*

Price of the sawdust	33 euro/ton
Transport 1-stage (distance 20 km)	2.86 euro/ton
Cost of pellet processing	90 euro/ton
Packaging	10 euro/ton
Transport 2-stage	2.86 euro/ton
Gross profit	41 euro/ton
Total price	**180 euro/ton**

-a- -b-

Figure 2. *View of the pellet manufactories in Elbasani (a) and Pogradeci (b) region*

4. ANALYSES OF WOODFUEL DEMANDS ACCORDING TO COUNTRIES

Based on the interviews with households and data provided from public forest service we have assessed the annual demands of fuel wood at family and national level in all studied countries. The results are given in the following table:

Table 6. *Annual demands of fuelwood for households based on data provided from field visits*

Country	Dwellings		Annual demands of woodfuel/ dwelling			Total demands for woodfuel		
	Rural area	Urban area	Firewood (mst)	Pellet (tonne)	Briquette (tonne)	Firewood (m^3)	Pellet (tonne)	Briquette (tonne)
Albania	396 800	361 800	12	5.5		2 856 960	2 182 400	
Macedonia	286 238	411 905	10-15		5	2 146 785		1 431 190
Montenegro	116 951	199 132	10-15		5	877 132		584 755
Kosovo	242 075	161 384	12.5		5	1 815 562		1 210 375

Note: the calculation of demand is carried out based on the number of dwelling in rural areas where the consumption is much higher than in urban areas

The total demands for wood fuel exceeds the supply for all countries involved in the study leading to maladministration of forest resources (see table 1). The situation is a bit different for Montenegro where there is approximately a balance between demands and supply offered by forest resources.

5. SWOT ANLYSIS OF WOOD FUEL SECTOR

This analysis intended to make evident the weaknesses, opportunities and threats occurred during the development of renewable energy sector at regional scale and use of forest biomass for energy production.

Table 7. *SWOT analysis for wood fuel in the studied countries*

Stakeholder group	Strengths	Weaknesses
Producers	✓ Renewable energy potentials, especially hydro energy ✓ Considerable number of private companies ✓ Low raw material costs ✓ Different typology of raw material ✓ Established local and somehow export markets. ✓ Environmental concerns aiming at EU level ✓ Trading legislation in accordance with EU ✓ Additional source of income ✓ Support to rural development	✓ Scarce quantities of raw material regarding to high level of processing ✓ Bad or medium quality of raw material base ✓ Most of the companies are ✓ very small ✓ Lack of supporting schemes ✓ Unsuitable working conditions; ✓ Low productivity ✓ Low dry capacities ✓ The lack of cultivation of the crops for biomass production ✓ Low awareness about RES potential ✓ Poorly developed consumer market ✓ Institutional capacity ✓ Infrastructure in energy sector ✓ Insufficient locally available know-how ✓ Production of equipment in the country
Users	▪ Competitive prices ▪ Ecological product ▪ Comfortable usage and storage (pellets & briquettes)	▪ Considerable investment for stoves/boilers regarding to pellets ▪ Non comfortable usage for other types of biomass. ▪

Stakeholder group	Opportunities	Threats
Producers	✓ Growing demand ✓ High potentials in foreign markets ✓ Investments in new/modern technologies and kiln-dry capacities ✓ High opportunities to maximal valuation of biomass products ✓ High opportunities increasing employment. ✓ International fund and investment program and donors ✓ Public procurements ✓ Projects financed through private sector ✓ Low labor cost	✓ Uncontrolled exploitation of the forests; (lack of biodiversity, erosion) ✓ Lack of domestic raw material ✓ Strong competition on the export markets ✓ Rising of wood biomass imports ✓ Lack of ability to reach and maintain the export quality. ✓ Import of wood biomass ✓ Strong competition from substitute products (fossil fuel etc.). ✓ Better quality of imported products; ✓ Lack of the ability to reach/maintain the export quality. ✓ Possibility of late payments
Users	▪ Construction boom creates great demand for such products; ▪ Investments in new technologies; ▪ Export demand.	

6. CONCLUSIONS AND RECOMMENDATIONS

The present situation of the woodfuel value chain in the studied countries showed that this activity is in the infancy stage and needs further development in the future. The vision for the development of wood fuel value chain consist in the diversification, strengthening and the well-ordering of the rings of the woodfuel chain recognized as an environmentally friendly, renewable, socially acceptable and widely established source of energy. The sustainable management of woodfuel value chain will enhance the share and the contribution of forest biomass energy in the national energy balance meeting the defined targets. The main purpose for this sector will be the increasing of renewable energy share from forest biomass to the sustainable economic development of energy sector. The achievement of this target will be attained by: (1) development and strengthening of a supportive enabling environment for wood fuel chain; (2) strengthening of marketing, trade and export; (3) increasing of the production, productivity and export; (4) strengthening of service delivery, cooperation, coordination and capacity building; (5) use of more efficient thermal generators for heating and installation of central heating systems in the public institutions; (6) improvement of energy efficiency via thermal insulation improvement and double glass windows.

For the future development of the woodfuel value chain the role of government in development and enabling of a favorable environment is very important. This role must be focused on the application of the subsidy (funding) schemes for the wood fuel producers. The establishment of a State Agency with government and donor funds will facilitate this process. The financial support for this sector could be provided by trading of carbon credits in the international market (e.g. Carbon Fund).

On the other hand the government should provide financial support for enabling silvicultural interventions especially in young forests as well as for establishment of fast growing specie's plantation for energy purposes. The establishing of such plantations with short rotation may help in increasing of the raw timber production. These plantations might be established on abandoned or lands with low productivity. Despite this another important instrument is the improvement of tax system for wood fuel producers (e.g. application of the tax free for all machineries that will used for wood fuel production such: pellet, briquette, and chips) as well as the improvement of credit conditions for logging companies with concession contracts focused on the activities related with renewable energy production.

During our field visits we noted the need for setting contacts between wood fuel producers and their organization in an association which will enable lobbing to government for fiscal instruments and other facilities. On the other side there is an urgent need for organization of cooperation between producers and salesman for ruling their business. We suggest the preparation of preliminary contracts between them avoiding the verbal contracts, arranging much better their activity. At present the relationships between seller (producers or traders) and users (public institutions or private) are characterized by a low level of cooperation. Organization of common meetings between all stakeholders aim to facilitate a dialogue between them. Such meetings will promote the enhancing of awareness of public institution managers (schools and hospitals) regarding to benefits of wood fuel products for energy use (e.g Elbasani region).

All pellet and briquette producers have emphasized the lack of information about the trend and prices of their products in the market. They also need to have information for a number of wood products that are used as raw material for their activity, their price and location.

More attention within the value chain must be paid to the establishment of linkages with export markets. We noted that only one producer in Pogradeci region (Albania) was exporting his products to Italy and Macedonia. The lack of technical specifications conform EU standards is preventing the wood fuel producers to export their products. For that reason they need to certify their products in order to have access in the European market. They have a good advantage because their products might be cheaper because of low wages for employee. Long-term supplying contracts between wood fuel producers and foreign buyers must be stimulated as a tool for healthy competition and implementation of international standards in the local market.

Modern techniques for forest logging are very important during timber harvesting in the forests. They will reduce the wood wastes after logging, will mitigate the negative impacts on environment and will provide better conditions for natural regeneration of forest areas. It is very important that residues that remain on the forest areas calculated to an amount of 20-30% of harvested timber to be further processed for chips production.

Investments are needed in all different segments of wood fuel value chain. Producers need to invest more in the technology of wood fuel production using also some auxiliary machines that help the preparation of raw material: such as grinding and packaging machines, drying rooms for raw material etc. We noted that all the producers were producing only one product, thus we suggest that they must extend the range of their wood fuel products.

Another important issue is the investments for improving energy performance in all public buildings. At all new buildings exist central heating systems, but the demands for investments in old buildings are high and government in all countries must invest for that. The energy efficiency at all countries was lower in rural areas where the main thermal generators were stoves with efficiency of 40 -50%. The energy produced by efficient woodfuel thermal generators is healthy for the children (e.g. kindergarden in Elbasani) and environmental friendly. Public institutions such as: schools, kindergarden and hospitals are very important users of briquette and pellets. For that reason is very important that public institutions to meet standards required for energy efficiency. These institutions must make investments toward the thermal insulation and investing on central heating systems. During field visits we identified a lot of cases where such investments are carried out in the schools, kindergarden and hospitals. On the other side long-term supplying contracts between wood fuel producers and public institutions must be stimulated. Another important issue was that investments regarding to energy efficiency from private buildings. They all must respect the energy code and must foresee investments to fulfill the standards required. We noted examples of improving energy efficiency in all new buildings, but still needs to make investments for old buildings.

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UDC 674.053

STUDY ON INTERDEPENDENCE BETWEEN TEETH FLATTENING, FEED SPEED, CUTTING HEIGHT AND QUALITY OF CUTTING SURFACE ON LOG BANDSAW PROCESSING

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ABSTRACT

Defining and determining of cutting process mechamism between the tool and the wood is the crucial factor for product quality, production quality, efficiency of the tool and production safety. Goal of the paper is to present research activities about the influence of teeth flattening, feed speed, cutting height on quality of cutting surface during log bandsaw processing. Studies of the effects are performed for values of teeth flatenning between 0,6 and 1,0 [mm], the feed speed between 10 and 30 [m/min] and the cutting height between 100 and 200 [mm].

Keywords: log bandsaw, wood processing, surface quality

1. INTRODUCTION

Wood cutting is a process that has decisive impact on product and production quality, tool performance, work safety, costs and productivity of the machine, as well as the overall production process.

For these reasons, the process of wood cutting has to be thoroughly studied, which will enable selection of optimal parameters and modes of processing, as well as meeting the requirements of all these factors.

2. MATERIALS AND METHODS

The objectives of the research are realized using log bandsaw with following technical features:

- Max log diameter	1150	[mm]
- Wheels diameter	1400	[mm]
- Max log length	8	[m]
- Cart opening	1250	[mm]
- Feed speed	0-50	[m/min]
- Cutting speed	30	[m/sec]
- Saw dimensions	1,47×180×9650	[mm]

Geometrical and angular parameters of the cutting tool are the following:

- Teeth spacing-pitch (t)	45	[mm]
- Teeth height (h)	15	[mm]
- Relief angle (α)	12	[°]
- Wedge angle (β)	54	[°]

- Rake angle (γ) 24 [°]
- Cutting angle (δ) 66 [°]
- Teeth profile PV
- Teeth flattening 0,6 / 0,8 / 1,0 [mm]

Variable input parameters:

- Cutting height 100 / 150 / 200 [mm]
- Feed speed 10 / 20 / 30 [m/min]
- Teeth flatenning 0.6 / 0,8 / 1,0 [mm]

Researched output parameters:

- Surface quality (roughness height) [µm]

3. RESULTS

The dependence between the cutting height, the teeth flattening and the surface quality for constant values of the feed speed is shown in Figure 1, Figure 2 and Figure 3.

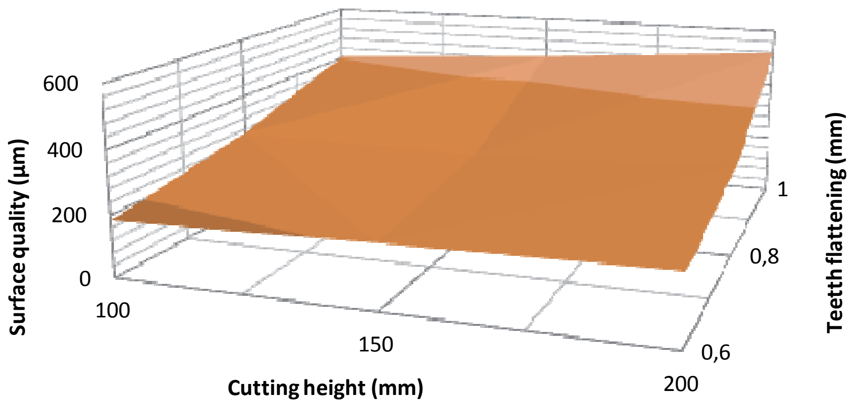

***Figure 1**. Dependence between cutting height, teeth flattening and surface quality for feed speed equal to u = 10m/min*

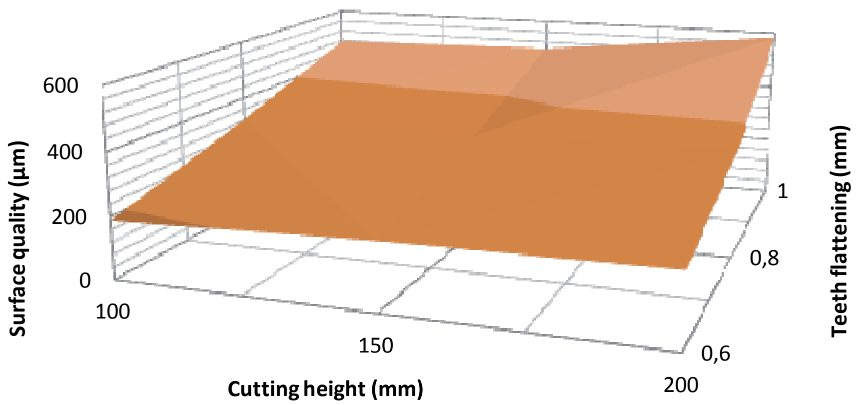

***Figure 2**. Dependence between cutting height, teeth flattening and surface quality for feed speed equal to u = 20m/min*

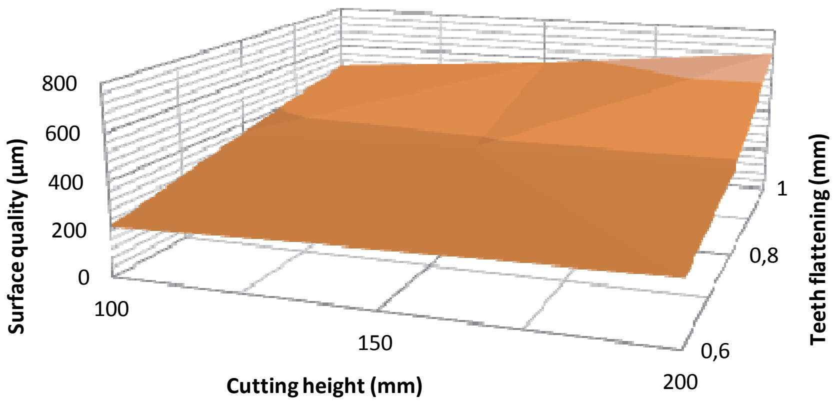

Figure 3. *Dependence between cutting height, teeth flattening and surface quality for feed speed equal to u = 30m/min*

The dependence between the feed speed, the cutting height and the surface quality for constant values of the teeth flattening is shown in Figure 4, Figure 5 and Figure 6.

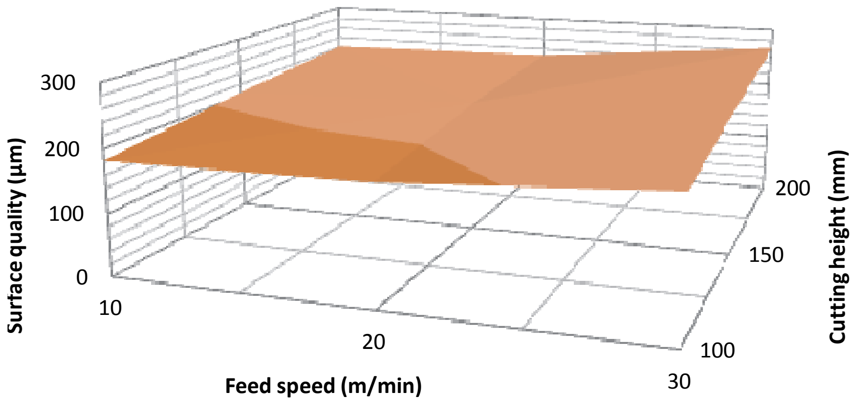

Figure 4. *Dependence between feed speed, cutting height and surface quality for teeth flattening equal to* Δ *= 0,6 mm*

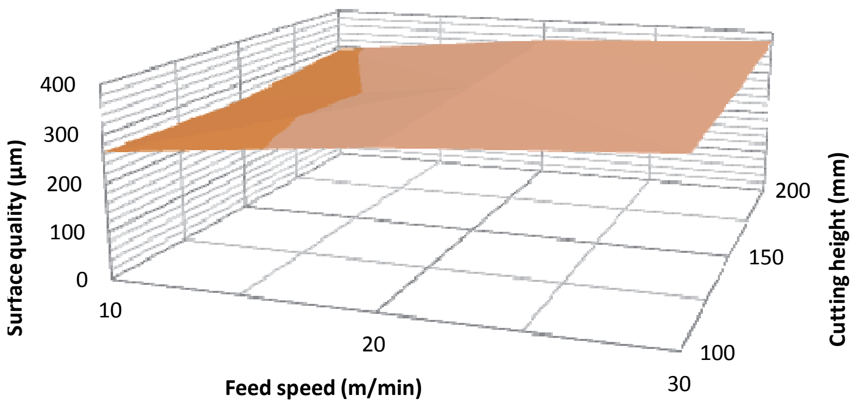

Figure 5. *Dependence between feed speed, cutting height and surface quality for teeth flattening equal to* Δ *= 0,8 mm*

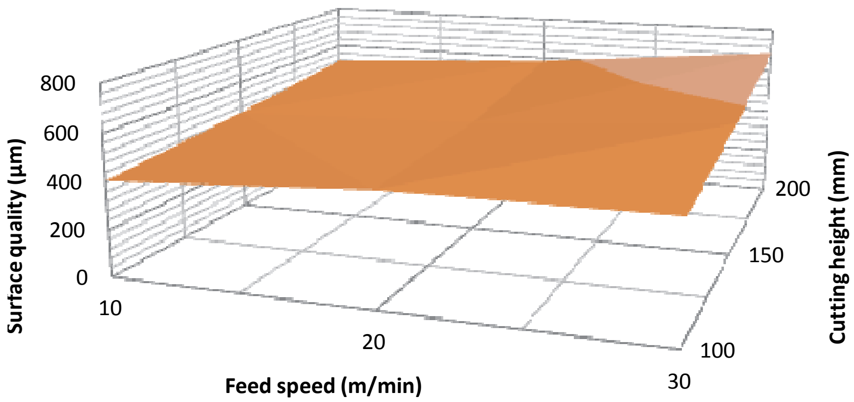

***Figure 6**. Dependence between feed speed, cutting height and surface quality for teeth flattening equal to Δ = 1,0 mm*

The dependence between the feed speed, the teeth flattening and the surface quality for constant values of the cutting height is shown in Figure 7, Figure 8 and Figure 9.

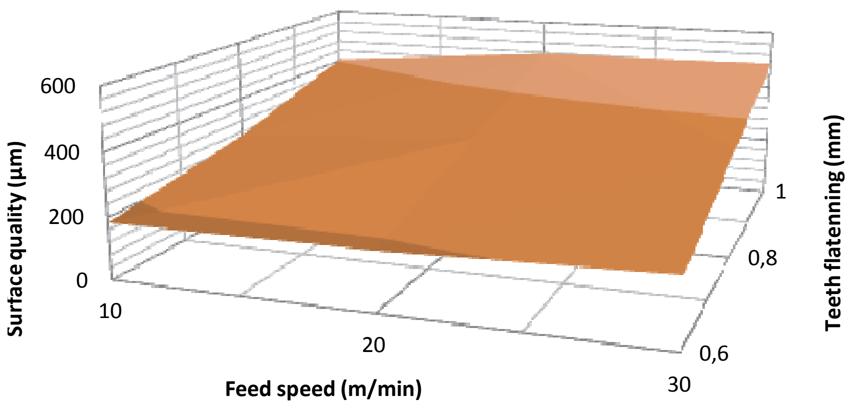

***Figure** 7. Dependence between feed speed, teeth flattening and surface quality for cutting height egual to h = 100 mm*

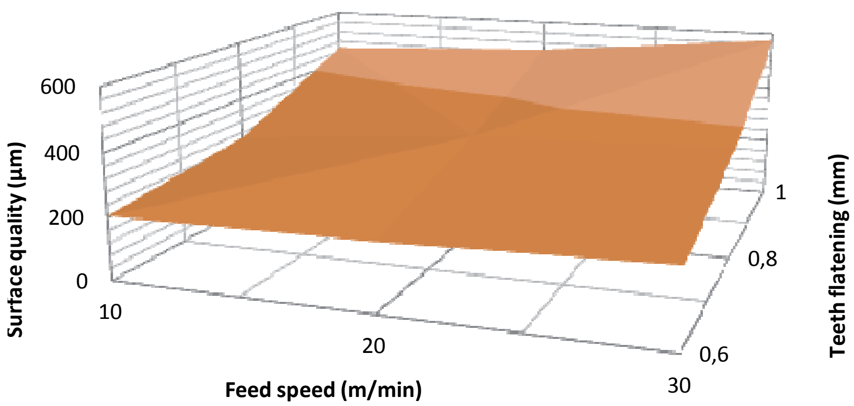

***Figure 8**. Dependence between feed speed, teeth flattening and surface quality for cutting height egual to h = 150 mm*

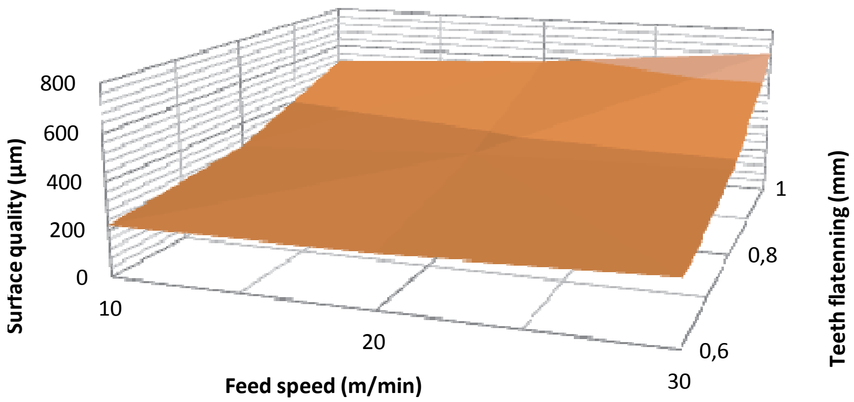

Figure 9*. Dependence between feed speed, teeth flattening and surface quality for cutting height egual to h = 200 mm*

5. CONCLUSIONS

- The quality of the machined surface decreases 8-27% as cutting height increase from 100 to 200 mm.
- The quality of the machined surface decreases 18-33% as feed speed increase from 10 to 30 m/min.
- The quality of the machined surface decreases 31-35% as tooth flatenning increase of 0,1 mm.

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ECOLOGICAL ASPECTS OF AIR AND WASTEWATER PURIFICATION FROM WOOD DUST LEFT FROM WOOD PROCESSING

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ABSTRACT

Wood dust consists of fine particles of wood floating in the air. Frequent inhalation of these particles causes various respiratory infections, acute and chronic ones, bronchopneumonia and even cancer. Greater content of wood dust causes skin drying and skin infections, eye redness and eye infections.

On the other hand, when wood particles get separated in cyclones, MOLDOW filters and wet separators, the land and rivers get polluted from wastewaters.

Because of these adverse impacts of wood particles, it is important to consider some techniques to reduce air and water pollution in wood industry.

During processing and treating wood, attention must be paid to the environmental issues, in order to protect both the workers and the environment. Usage of respiratory protective equipment, appropriate wood particles separators, dry and wet filters and precipitators, all these aspects are of crucial importance for environmentally healthy workplace and ecologically healthy environment.

Key words: ecology in wood industry, wood dust, air and water pollution

1. INTRODUCTION

Industry generates a lot of air and water pollutants, each of them specific and depending on the production process applied. There are five basic pollutants: carbon monoxide, carbon-hydrates, nitrogen oxides, sulfur oxides and **particles of substances (dust, fume**). Main industry branches causing air pollution are: machines operating on fuel burning, industry and other branches using solvents, inorganic and organic chemical industry, food industry, mineral products industry, oil industry, metallurgy and **wood processing industry.**

Pollution of the atmosphere (including polluted indoor space) affects human health. It is manifested as: **acute diseases** (World Health Organization established that 2,4 million people have died as a consequence of air pollution, and indirectly because of soil pollution), **chronic diseases (**asthma, bronchitis, emphysema of the lungs, heart and lungs failure and respiratory allergies), **changes in physiological functions (**respiratory functions, oxygen transport in the blood), **psycho-physiological reactions, irritations, appetite and sleep disorders**.

Particles or wood dust (dust matters /DM/). DM10 present a fraction of particles with diameter up to 10 micrometers which get arrested in the nose. DM2,5 are particles whose size is up to 2,5 micrometers and they penetrate into the bronchi and lungs.

Wood dust in the air after wood processing is dangerous for human health. Inhaled floating particles cause numerous problems in the respiratory tract, from various infections to lung cancer. A lot of researchers have found wood dust to be cancer-causing substance, especially oak and beech wood dust. It is possible to decrease the workers' exposure to wood dust using technical, administrative methods and personal protection equipment. Waters polluted by human activities can be divided into: industrial water, agricultural water and the like.

Water pollution means input of various pollutants into rivers, lakes and ground waters. It happens when polluting substances are recklessly released into water, directly or indirectly, and later that water is released without prior purification.

Wastewaters are produced in many locations, in many ways and in huge amounts. Wastewaters are present in wood industry, too. Almost all of our rivers are slightly or severely polluted. For example, the water in our longest river Vardar throughout its flow in the R. of Macedonia can be classified in the fourth and fifth group, which means it is polluted. This applies to the Vardar's biggest confluents, Crna Reka and Bregalnica

2. SUBJECT AND GOAL

Subject of this paper is wood dust and the fine particles generated from wood while being processed , and air and wastewater pollution caused by this wood dust.

The aim of this paper is to offer solutions for direct protection of respiratory tract, as well as ways of separation of wood particles, in order to prevent pollution of the environment, by directing and channeling wastewaters.

3. TECHNICS FOR REDUCING AIR AND WASTEWATERS POLLUTION DURING WOOD PROCESSING

Particles of wood dust remain in the air surrounding and inside the wood processing plants, often because of faulty or improperly designed systems for pneumatic transport. An indicator for high content of wood dust in the plant is dryness of the mouth and throat, sore eyes and dry skin. The problem is solved technically with:

- checking and ensuring that pipes of the pneumatic transport devices are hermetically tight-proof.
- checking the condition of the receivers in the machines which produce most wood dust (grinders) , i.e. their ability to accept and release wood dust, removing the defects or making new receivers with increased acceptance capacity.
- mini water curtains are placed in the immediate vicinity of the work place, in the zone with critically high content of wood dust,
- increasing the speed of the mixture in the pipes, up to 32 m/s (ms^{-1}).

- Usage of respiratory masks is recommended as additional protection, because they prevent wood dust from entering the respiratory tract (Figure 1).

Figure 1. *Respiratory masks for dust protection of the respiratory tract*

Treatment of polluted waters guarantees removal of pollutants from wastewaters. The treatment can be done in a physical, chemical or biological way. Wastewater is most commonly treated in the vicinity of the place of origin, or is transported by pipes to a common treatment device. There are three steps in conventional wastewater treatment: primary, secondary and tertiary.

Primary treatment includes temporary keeping wastewater in a pool where heavy solid substances settle down on the bottom of the pool.

The secondary treatment involves removal of dissolved and suspended biological substances. It is commonly performed by water microorganisms. During the secondary treatment, it might be necessary to employ a separation process in order to eliminate the microorganisms from the water treated, prior to its release or tertiary treatment.

Tertiary treatment is sometimes defined as something more than primary and secondary treatment. Treated water is sometimes disinfected chemically or physically (for example, by lagoons and by micro-filtration) before it is released into a stream, river, lake, shore, lagoon or marsh, or it can be used for watering golf courses or parks. If it is clean enough, this water can also be used for refreshment of ground waters or for agricultural purposes.

Solid waste is actually remains of an original material (wastewater) which microbes can not decompose. Digestate is substance rich in minerals, cellulose and remnants of dead bacteria from the digester. Basically, it is very similar to compost, so it is used for fertilizing plants.

The following categories of measures could be applied to control water pollution:

- minimization and utilization within the activity frames,
- separation of solid particles,
- filtration,
- air flotation,
- sedimentation/separation,
- chemical reaction,
- steaming
- sanitization
- biological treatments,
- incineration

Separation of solid particles, i.e. wood dust can be done in numerous ways; we will present the most commonly used ones:

- Inertial separators (cyclones);

They are used to separate solid matters (wood dust) from gasses (the air). Separation is based on the inertial-centrifugal forces which cause wood particles to "escape" to the periphery, thus letting the central air become completely or partly clean before going out through the central pipe. These devices are able to separate rarely up to 98% of the solid substance, provided they are well designed and appropriately chosen. Return and reuse of the warm air in working space is not recommended.

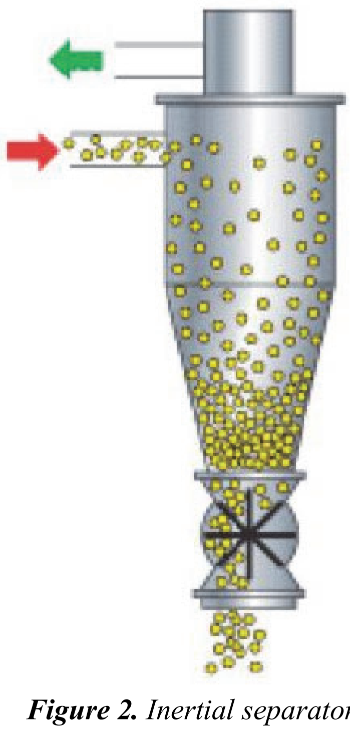

Figure 2. *Inertial separators (cyclones);*

- Filtration with baggy filters;

Baggy (sleeve-like) filters are also referred to as MOLDOW separators. They contain numerous bags and sleeves placed on a common structure. The mixture enters the outside cylinder. Because of prompt reduction in speed, the wood settles down in the lower part and the finest particles move towards the sleeves where they remain in the cloth. The air passes through the cloth and reaches the atmosphere. When the weather is cold, it is allowed and recommended to return warm air into the plant.
The deposited wood dust is used as fuel for the boilers.

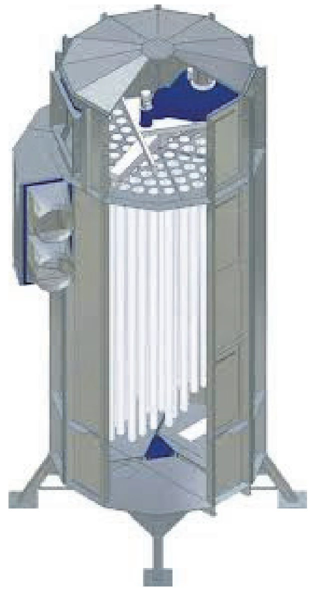

Figure 3. *Filtration with baggy filters*

- Scrubbers (wet separators);

Wet separators are devices which help to remove even the finest particles. The operation principle of these devices is colliding wood dust particles with tiny drops of water. Separation efficiency depends on the size of particles and drops, their speed, as well as the ratio between liquid (water) volume and air volume. Inertial forces action is of crucial importance, and the relative speed of the particles should be as high as possible in relation to the speed of the drops. Purified air is released into the atmosphere; it is recommended to bring it back when the weather is warm, because it is cooled and accordingly will be favorable for the working effects.

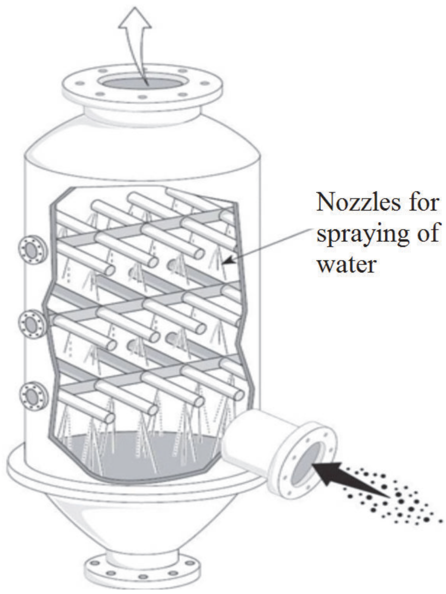

Figure 4. *Scrubbers (wet separators)*

In wood industry wastewater obtained from wet separators is led to concrete pools where solid particles are left to settle down. Water which is partly purified is most commonly released to flow through various channels towards the nearest running waters. In this way it is still possible to partly pollute nearby running waters. The residue in the pool is stored at places where after it gets dry, it is blown away in the surrounding environment.

Figure 5 (orig.) illustrates a concrete suggestion for treatment and purification of these wastewaters.

The water containing wood dust gets into the pool, in its first part designed for sedimentation. At the beginning of this part there is a coarse mesh whose task is to settle water and possibly to keep bigger wood particles. Particles tend to settle down. Particles that have passed through the mesh continue to deposit. After mesh treatment, air is blown in through nozzles in the upper part of the device, in order to provide aeration of the water. Water which is largely purified floods into the second part where additional sedimentation happens. In this part it is possible, but not obligatory, to add small contents of coagulation additives which will cause additional sedimentation of the finest particles.

Water treated and purified in this way can be used as technical water which will again return to the wet separators. The sediment from the lowest points of the first part of the pool is carried away and mixed with earth in predefined ratio. Earth formed in this way has properties of compost and can be used for horticultural needs or for fertilization of farmland.

According to the statistic data from 2001 to 2010, mostly fresh technical waters were used for technological purposes (99%).

In 2010 out of total of 4398 million m^3 fresh water used in the industry, 4198 million m^3 were technical waters.

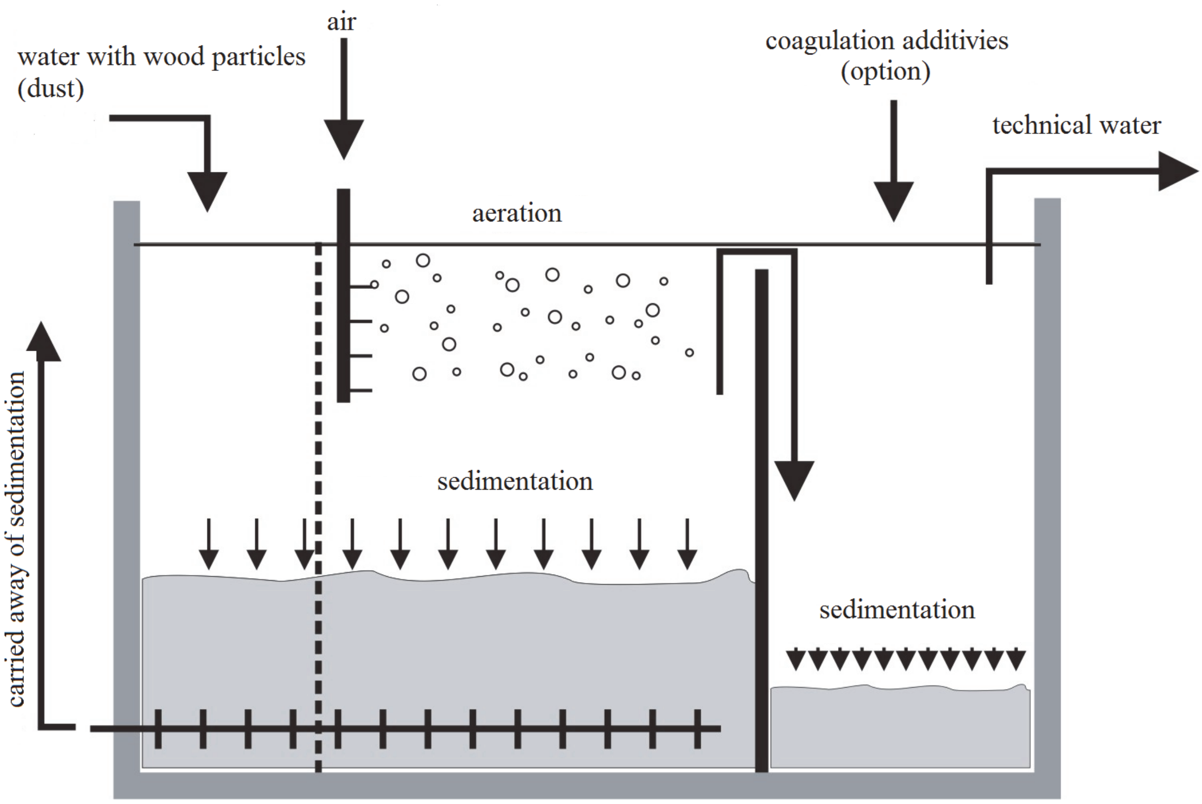

Figure 5. *Proposed design for precipitator for wastewaters in wood industry, combined with aeration device and part for coagulation (orig.)*

Release of technical water is performed in dedicated recipients. Recipients of wastewaters could be soil, sewage, running waters, accumulation lakes and natural lakes. In 2010 out of total of 6221267 thousand m^3 released non purified wastewaters generated by industry, 7,2 % i.e. 449584 thousand m^3 were released into sewage, 92,3% i.e. 5742362 thousand m^3 into running waters, and the rest was directed to the accumulation lakes and soil.

In the Republic of Macedonia, only about 3-4% of total amounts of wastewaters are treated and purified. Out of total of 20131 thousand m^3 wastewaters treated in 2010, about 2.0% were generated by power stations, 58,2 % came from processing industry and 39,75 from mining industry.

In 2010 from the total amount of wastewaters - 20131 thousand m^3, 10283 thousand m^3 or 51% were released in soil, 8000 thousand m^3 or 39,7% were released in accumulations, 188 thousand m^3 or 0,9% were released in sewage and 1660 thousands m^3 or 8,4% were released in running waters.

The greatest quantities of wastewaters in 2010 were generated in production processes – 89,0% or 1277244 m^3, in cooling processes 2,8% or 40161 m^3 and about 5,7% or 81648 m^3 was sanitary water.

4. DISCUSSION AND RESULTS

Not only wood dust but any dust, regardless its contents, is harmful for human health. In case of increased content of wood dust, especially oak and beech wood dust (cancer-causing substances), wearing protective masks is a must-do. This will decrease the number of sick leaves caused by frequent diseases of the respiratory tract.

Proper separation of sawdust, shavings and wood dust has a crucial importance in preventing pollution of the surrounding environment (nearby the plants) and pollution of the wastewaters. When baggy filters (MOLDOW) and scrubbers are used, air purification is almost thorough. The difference is that baggy filters leave dry wood dust, and the scrubbers leave wet wood dust. Dry wood particles are used as fuel in boilers.

Wet separators (scrubbers) are recommended to be used in all wood processing and treating plants, even combined with baggy filters. The only problem is that wastewaters are generated. That is why water must not be released directly but after the scrubbers a pool must be fitted, where solid particles (fine wood dust) will settle down. Water filtered in this way is ecologically clean and can be released. The sediment must not be released into running water.

Our suggestion for using precipitator as water purifier, combined with aeration system and optionally coagulation with harmless chemical substances, provides a closed system which, firstly, does not generate wastewaters outside the factory, and secondly, the sediment (from the first fraction) mixed with soil can be used as compost. Compost, thanks to its utility, will recreate conditions for self-sustenance of the treatment and purification system.

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AIR SEASONING OF WALNUT BOARDS WITH THICKNESS OF 50,0 mm

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ABSTRACT

In the paper are presented the results of air seasoning of walnut boards as a row material with 50,0 mm in thickness. In this order during the drying, a total number of 12 boards were investigated.. The period of investigation lasted from March until December 2008. The results show that boards were air dried from initial average moisture content of 50,10% to final average moisture content of 15,26%. The temperature and relative humidity of the air within this period of time varied from 5,6 ^{0}C to 28,5 ^{0}C and from 49,0 % to 72,0 %. The investigations were performed in the Republic of Macedonia.

Key words: walnut, boards, air seasoning, wood moisture content, temperature, relative humidity of air

1. INTRODUCTION

The term air seasoning of the wood means the process of reducing of moisture content in the wood of an open or covered area under the influence of natural external climatic conditions. In our climatic conditions air wood drying is performed at the temperatures between – 25 ^{0} C and 40 ^{0} C. In our practice, air drying (seasoning) of the wood is often used in combination with drying in dry kiln. It lasts quite a long time and depends on the wood species, initial wood moisture content, level of wood processing, local climatic factors etc. On the duration of the process of air drying have an impact the following factors: relative humidity of the air, temperature of the air, air velocity, insolation, phytopathological disease,etc..

2. MATERIAL AND METHODS

For each board there are three places for wood moisture measuring. The lumber was piled under the shed. In the pile there were board samples with the following dimensions: 1,50 m length, 20,0 cm width and 50,0 mm thickness.

The measuring places are positioned about 500,0 mm from the head and in the middle of the sample width. For a correct reading of the wood moisture it is necessary to plant the electrode at a 1/3 of the board thickness (Figure 1).

Mathematical model of formula was used to calculate the corresponding parameters, while some of the data was processed by the method of variation. The measuring places are positioned about 500,0 mm from the head and in the middle of the sample width.

3. RESULTS AND DISCUSSION

We performed several experiments on each boards in order to evaluate the performance of air seasoning in R. of Macedonia. In this section, we present some of the most significant results relating to temperature of the air, relative humidity of the air and wood moisture content during the test period.

The statistical data was processed in order to obtain relevant results for the temperature and relative humidity of the air. The results are shown in Table 1 and Table 2.

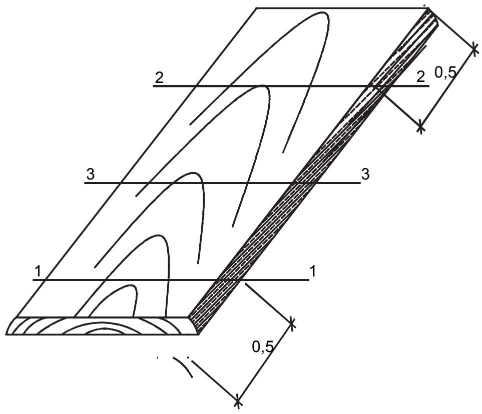

Figure 1. *Measurement points for determination of wood moisture content*

Table 1. *Statistical data for the temperature of the air*

Month	**Xsr ± fxr**	**σ ± fσ**	**V ± fv**
March	10,8 ± 0,33	1,68 ± 0,23	15,58 ± 3,26
April	18,52 ± 0,60	3,04 ± 0,43	16,43 ± 3,46
May	20,32 ± 0,68	3,41 ± 0,48	16,79 ± 3,54
June	22,76 ± 0,82	4,12 ± 0,58	18,12 ± 3,86
July	28,52 ± 0,49	2,45 ± 0,34	8,59 ± 1,71
August	27,44 ± 0,49	2,48 ± 0,35	9,05 ± 1,81
September	24,28 ± 0,61	3,07 ± 0,43	12,66 ± 2,61
October	19,28 ± 0,45	2,28 ± 0,32	11,83 ± 2,43
November	10,76 ± 0,45	2,25 ± 0,31	21,00 ± 4,57
December	5,68 ± 0,35	1,77 ± 0,25	31,21 ± 7,45

Table 2. *Statistical data for the relative humidity of the air*

Month	**Xsr ± fxr**	**σ ± fσ**	**V ± fv**
March	66,8 ± 0,62	3,13 ± 0,44	4,69 ± 0,93
April	60,32 ± 0,94	4,74 ± 0,67	7,87 ± 1,57
May	59,72 ± 1,42	7,12 ± 1,00	11,93 ± 2,45
June	55,12 ± 0,60	3,00 ± 0,42	5,45 ± 1,09
July	49,64 ± 0,57	2,85 ± 0,40	5,75 ± 1,15
August	49,04 ± 0,59	2,96 ± 0,41	6,04 ± 1,20
September	56,16 ± 0,79	3,97 ± 0,56	7,07 ± 1,41
October	56,36 ± 0,44	2,21 ± 0,31	3,93 ± 0,78
November	63,96 ± 1,66	8,30 ± 1,17	12,99 ± 2,68
December	72,00 ± 0,88	4,41 ± 0,62	6,13 ± 1,23

According to the data shown in Table 1, it can be concluded that the temperature of the air varies from minimum of 5,68 ^{0} C in December up to maximum of 28,52 ^{0} C in July. Further, we can see from

Table 2 that relative humidity of the air has minimum value of 49,04 % in August and maximum value of 72,0% in December.

The wood moisture content values on the basis of 180 measurements obtained during the investigation are given in Table 3. The wood moisture min. value of 11,0 % was measured in September and max. value of 48,8% in March.

Table 3. *Wood moisture content values from March until December 2008*

Place of measurement	March	April	May	June	July	August	September	October	November	December
	Wood moisture content (%)									
1	50,1	47,9	44,0	38,0	26,8	15,5	14,0	13,2	12,8	15,0
	50,4	44,2	42,0	36,5	25,4	14,0	12,4	11,0	14,6	14,8
	50,0	48,9	43,0	35,1	24,0	13,0	10,8	14,0	16,0	14,8
	48,8	46,8	44,0	33,8	24,4	14,0	13,2	12,8	15,5	15,0
	50,5	48,4	43,0	30,0	21,2	13,0	11,3	14,0	13,6	15,0
	48,8	47,9	44,0	29,8	18,0	10,9	14,0	13,2	14,0	15,3
2	52,0	48,5	44,6	39,0	28,0	16,2	12,0	13,0	14,5	14,8
	52,5	47,4	44,8	38,5	27,4	14,8	13,4	12,0	15,2	15,6
	49,6	49,0	43,8	36,4	26,5	14,8	11,5	14,0	15,4	16,6
	49,0	47,5	44,3	35,7	26,0	15,2	12,8	13,5	14,8	15,9
	51,0	48,8	44,5	32,0	24,0	13,2	14,0	14,7	14,5	16,0
	51,0	48,7	43,0	32,4	22,1	12,4	14,5	14,6	13,9	16,0
3	51,2	48,0	44,0	37,0	26,0	16,5	12,0	13,5	12,7	14,4
	51,0	47,0	43,0	36,2	28,2	12,0	14,0	12,0	15,4	15,0
	48,4	49,0	43,0	35,0	26,0	13,0	11,0	14,0	15,2	16,0
	48,6	48,0	44,0	34,0	23,9	15,2	12,0	13,7	15,4	14,0
	49,6	49,0	45,0	31,2	22,0	12,0	10,8	14,2	14,4	15,5
	49,4	49,0	44,0	31,0	20,4	11,5	12,3	14,3	12,9	15,1

Data shown in Table 3 was used to estimate the average moisture content during every month within the time period of investigation.(Table 4).

Table 4. *Statistical data for wood moisture content*

Month	Xsr ± fxr	σ ± fσ	V ± fv
March	50,10 ± 0,23	1,18 ± 0,16	2,37 ± 0,39
April	48,00 ± 0,23	1,18 ± 0,16	2,46 ± 0,41
May	43,77 ± 0,15	0,78 ± 0,11	1,79 ± 0,29
June	34,53 ± 0,58	2,91 ± 0,41	8,43 ± 1,40
July	24,46 ± 0,56	2,80 ± 0,39	11,47 ± 1,95
August	13,73 ± 0,32	1,64 ± 0,23	12,01 ± 2,04
September	12,55 ± 0,24	1,22 ± 0,17	9,77 ± 1,62
October	13,42 ± 0,19	0,98 ± 0,13	7,31 ± 1,21
November	14,48 ± 0,19	0,99 ± 0,14	6,87 ± 1,14
December	15,26 ± 0,13	0,65 ± 0,09	4,28 ± 0,71

From Table 4 we can conclude that from March to December the moisture content has a trend of increasing from 50,86 % to 15,26 %. Moreover, the moisture content of the wood has a min. value of 12,55 % registered in September.

4. CONCLUSIONS

The air seasoning of the wood becomes an increasingly attractive type of drying especially among the big size wood working company. Many company use natural drying in order do have economic benefit in wood drying process at all. Average statistical values for the temperature of air vary from 5,68 ± 0,35 ^{0}C to 28,52 ± 0,49 ^{0} C. Average statistical values for the relative humidity of air vary from 49,04 ± 0,59 to 72,00 ± 0,88 %. Minimal value of wood moisture content of 12,55 % was obtained in September.

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