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Mehran Roohnia[1]

An Estimation of Dynamic Modulus of Elasticity in Cantilever Flexural Timber Beams

Određivanje dinamičkog modula elastičnosti drvenih konzola

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ABSTRACT • *Due to considerable influence of shear deflection and rotary motion, the modulus of elasticity is hardly obtainable in fixed-free flexurally-excited (cantilever) beams. For isotropic materials, Timoshenko has proposed a set of curves to correct the fixed-free modal frequencies as the radius of gyration and free length; however, its performance for wood was not sufficiently conclusive. In this study, rectangular beams of pine wood were tested in a fixed-free condition, altering the free length to height ratios in a proper extent and comparing them to their reference free-free data in terms of natural frequency and dynamic modulus of elasticity shifts. The equality of two pairs of fixed-free versus free-free data, for both frequency and dynamic modulus, was significantly confirmed. The correlation coefficient between experimental and calculated fixed-free frequencies was high enough, and however the correlation coefficient of the modulus of elasticity was rather low.*

Keywords: *assessment, cantilever beam, flexural, nondestructive technique (NDT), Timoshenko, vibration, wood*

SAŽETAK • *Zbog utjecaja otklona smicanjem i rotacijskog pomaka vrlo je teško odrediti modul elastičnosti konzolnih greda opterećenih na savijanje. Za izotropne materijale Timošenko je predložio skup korekcijskih krivulja za modalne frekvencije konzolnih uzoraka u ovisnosti o radijusu otklona i duljini slobodnog kraka. Međutim, njihova preciznost za drvo nije bila zadovoljavajuća. U prikazanom istraživanju analizirana su svojstva konzolnih greda od borovine pri promjeni omjera slobodne duljine i visine grede u odgovarajućoj mjeri i u usporedbi s prirodnom frekvencijom i dinamičkim modulom elastičnosti slobodne grede. Rezultati istraživanja pokazali su da ne postoji statistički značajna razlika u frekvenciji i dinamičkome modulu elastičnosti između ispitivanih uzoraka u svojstvu slobodnih greda i onih koji služe kao konzole. Koeficijent korelacije između eksperimentalne i proračunske frekvencije za konzole bio je vrlo visok, iako je za isti primjer konzole koeficijent korelacije za dinamički modul elastičnosti bio vrlo malen.*

Ključne riječi**:** *procjena, konzole, savijanje, nedestruktivno ispitivanje (NDT), Timošenko, vibracije, drvo*

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1 INTRODUCTION
1. UVOD

By definition, a cantilever beam is a beam having one end rigidly fixed, thus preventing any displacement and rotation at the supported end, whereas the other end is free to deform. Due to shear deflection and rotary motion, the modulus of elasticity is hardly obtainable in fixed-free flexurally-excited (cantilever) beams. The present study was made on the basis of a study on fixed-free timber beams done by Shafiee (2010) and Roohnia *et al*. (2011b. Meanwhile, the initial experience in isotropic elasticity was considered quite promising.

With isotropic materials, a large number of studies have been conducted to explain the dynamic characteristics of beam structures (Gurgoze and Batan, 1986; Jang and Bert, 1989; Rossi and Laura, 1990; Farghaly, 1992; Auciello, 1996; Banerjee, 1999; Lee, 2009). Negahban (1999) examined the deflection, frequency and practical uses of cantilever beams under vibration. He demonstrated that if a beam was covered by a thin film, the flexural rigidity altered. The subsequent changes affected the vibration frequency shift. In this case, if the frequency shift was measured, the film elastic modulus could be calculated. Yu (2009) studied free and forced flexural vibration analysis of cantilever plates with attached point mass. He investigated the effects of mass ratios and locations of the point mass on Eigen values and modal participation factors for square and rectangular plates. Similarly, Alzaharnah (2009) considered the flexural characteristics of a cantilever plate heated from the fixed end. Caruntu (2009) was concerned with free transverse vibrations of non-uniform homogeneous beams, while Chondros and Dimarogonas (1998) analyzed the vibration of a cracked beam. Damages and cracks were also studied by Leonard *et al*. (2001), Radhakrishnan (2004), Orhan (2007), Il'gamov and Khakimov (2009) and Roohnia *et al*. (2010, 2011a).

Longitudinal dynamic modulus of elasticity, as the most important mechanical characteristic of timber rectangular beams, could be evaluated through several vibration methods such as free or forced, flexural or longitudinal vibration of a beam in several supporting conditions (Bodig and Jayne, 1993). A real free-free condition (if possible) might be more favorable as a reference method due to lack of any effects from supports to the vibration of the beam. In wood science, natural vibration analysis is often used to characterize the longitudinal and shear modulus of elasticity in various geometrical types of prismatic beams. Free vibration of a free-free beam was deeply discussed by Brancheriau and Bailleres (2002), who considered a broad range of theories and different directions of vibration. A lateral or axial percussion at one end of the beam set up on elastic support produces flexural or longitudinal vibrations. Formulating a hypothesis for homogeneity of geometrical and mechanical properties of the beam, the basic dynamics theorem can be applied to obtain the motion equations of longitudinal and transverse vibrations. The resolution of the differential equation for transverse motion leads to the search for solutions to the frequency equation (Brancheriau and Bailleres, 2002). Since there are no exact analytical solutions, they analyzed several approximate approaches. In their report, the effects of the elastic supports, the shear modulus and the height to length ratio were discussed. They presented the most common theoretical models and defined their validity range, application conditions, and accuracy levels with respect to measured values.

As the position of a member in a timber structure varies largely relative to its end supports, solving the vibration equations for the above-mentioned support conditions would be satisfactory, since extracting these members for carrying out a free-free test would be especially harmful to an old structure. The vibration equations, therefore, should be developed based on their original position or by in-situ examinations. This study of free flexural vibrations in a cantilever beam was a continuation of previous research (Shafiee, 2010; Roohnia *et al*., 2011b) that rarely dealt with timber beams in literature.

To determine the relative magnitude of shear deflection in terms of an idealized solution, Timoshenko defined a correction factor as the radius of gyration divided by free length in which the correction coefficient depended upon the ratio of specimen thickness to specimen length (Harris, 2002; Turk *et al*., 2008). Timoshenko presented a set of curves to determine the correction factor in six initial modes of flexural vibration. Its performance for wood with different dynamic responses in LR and LT flexural vibrations (where LT and LR correspond to the relative plane of flexure) was, however, not sufficiently conclusive (Roohnia *et al*., 2011b). In 2008, Turk *et al*. did not compare the obtained moduli of elasticity through vibration of fixed-free beams with any other certified method but found it applicable for orthotropic materials such as wood considering the repeatability of the testing procedure. A comparative study of flexural vibration of fixed-free and free-free beams, with no correction algorithm for shear deflection, rotary motion or any other unverified potential confusion, was done with absolutely clear timber beams of similar dimensions (Shafiee, 2010; Roohnia *et al*., 2011b). The aim of this article was to find a frequency correction method for cantilever timber beams other than the one proposed byTimoshenko

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Theories
2.1. Teorije

Based on Euler-Bernoulli's elementary equations of bending, the dynamic flexural modulus of elasticity of a beam is evaluated under flexural free or forced free vibration as follows:

$$\left(\frac{E_d}{\rho}\right)_n = \left[\frac{4\cdot\pi^2\cdot l^2\cdot f_n^2}{\alpha\cdot m_n^4}\right] \quad (1)$$

where, E_d is dynamic modulus of elasticity (Pa), ρ is stabilized density (kg·m^{-3}), *n* is mode number, *l* is free length (m), f_n is frequency of n^{th} mode (Hz), m_n is a constant related to support condition and mode number (for the fundamental frequency, m_1 is equal to 4.73 for a free-free condition and 1.785 for a fixed-free condition; Bodig and Jayne 1993). α is the square value of gyration radius divided by free length, equation (2)

$$\alpha = \left(\frac{\sqrt{I/A}}{l}\right)^2 = \frac{I}{A\cdot l^2} \quad (2)$$

Equation (1) is an idealized equation of vibration that neglects the effects of shear force and rotary motion in the specimen. However, the application of this equation is limited to some proper *l/h* ratios (greater than 20 in a free-free condition or greater than 58 in a fixed-free condition). To determine the relative magnitude of shear force in terms of the idealized solution in a fixed-free isotropic beam, Timoshenko introduced a set of curves to obtain the correction factor defined by the radius of gyration and free length (Harris, 2002; Turk *et al*., 2008) (Fig. 1).

Therefore, if care is taken to control the ratio of thickness divided by free length, the radius of gyration divided by free length (Equation (2)) is <0.005 (dimensionless), and the frequency correction factor approaches 1.0 where shear and rotary effects are negligible (Turk *et al*., 2008).

The flexural dynamic modulus of elasticity is also evaluated using Timoshenko's theory of bending (an improvement for Euler-Bernoulli's elementary theory of bending), fitting a trend line among three or more points with the coordinates of (x_n, y_n), n=1, 2, 3, …, calculated from three or more initial modes of flexural free-free vibration considering a proper correlation coefficient, R. The intercept in Timoshenko's trend line is a specific modulus and its slope is the ratio of modulus of elasticity to the shear modulus (Bordonné, 1989; Brancheriau and Bailleres, 2002; Roohnia *et al*., 2006, 2010) (Equation (3)):

$$y = \left(\frac{E_d}{\rho}\right) - \left(\frac{E_d}{K\times G_{ij}}\right)\cdot x,\ R^2>0.99 \quad (3)$$

where, *K* is shape coefficient (the value of 5/6 can be used for a rectangular cross section and 0.9 for round cross sections; Harris, 2002) and G_{ij} *is* shear modulus in vibration plane (G_{LT} or G_{LR}).

Higher correlation coefficients of the estimated trend lines in Equation (3) produce homogenous specimens, where the Timoshenko's theory has been fitted initially to isotropic materials. Decreasing the isotropic behavior would result in lower correlation coefficients. It is obvious that wood defects would decrease its axial isotropic (orthotropic) characteristics.

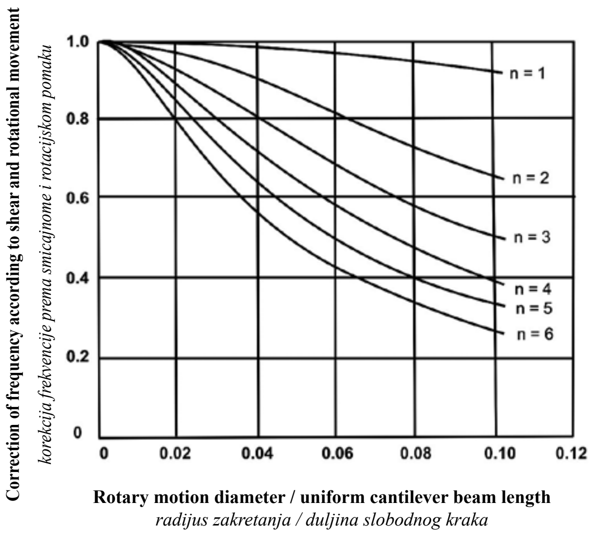

Figure 1 Influence of shear force and rotary motion on natural frequencies of uniform cantilever beams; *n* is mode number (Harris, 2002)
Slika 1. Utjecaj sile smicanja i rotacijskoga gibanja na prirodnu frekvenciju uniformiranih uzoraka konzola; *n* je broj modova (Harris, 2002)

2.2 Experiments
2.2. Eksperimenti

Free vibration of a free-free bar, a method for evaluating the dynamic modulus of elasticity of clear timber elements with an acceptable deviation (10-15 %), compared to that of standard static bending has been confirmed analytically and experimentally in literature (Bodig and Jayne, 1993; Cai *et al*., 2000, Brancheriau and Bailleres, 2002; Yang *et al*., 2002; Divos and Tanaka, 2005; Liang and Fu, 2007, Madhoushi *et al*., 2008, Roohnia and Tajdini, 2008). Accordingly, this method could be used to obtain the reference values of modulus of elasticity.

For starting the experiments, 20 pieces of visually clear rectangular beams with the dimensions of 50×20×500 mm (width×height×length) (RTL) were prepared in accordance with ISO 3129, from a visually graded pine lumber. The specimens were dried softly at 60 °C for 72 hours, and conditioned in a climatic chamber at the relative humidity of 65 % and temperature of 20 °C for a few weeks until the moisture contents were stabilized (conditioning started from zero point). Based on Bordonné's solution for Timoshenko's theory of bending (Bordonné, 1989), and considering Timoshenko's correlation coefficients higher than 0.99, 16 out of 20 measurements were accepted as the selected samples to be taken into account for further analysis.

A total of 16 reference dynamic flexural modulus of elasticity values were selected for 16 specimens, and evaluated in free flexural vibration of free-free beams, where Bernoulli's elementary theory was used for elasticity evaluations. Equation (1) was solved for natural frequency of fixed-free beams where the reference free-free modulus was used:

$$f_c = \left(\frac{\alpha \cdot 1.875^4 \cdot E_d}{4 \cdot \pi^2 \cdot l^2 \cdot \rho} \right)^{\frac{1}{2}} \quad (4)$$

where, f_c is the calculated fundamental frequency in fixed-free condition.

Experimental frequency of the fundamental mode, f_e, was evaluated in fixed-free condition (Fig. 2), while altering the free length, stepwise from l=0.96 · L to 0.88 · L, 0.8 · L, 0.72 · L, 0.64 · L and 0.56 · L (48, 44, 40, 36, 32 and 28 cm, respectively), and relative shifts of fixed-free fundamental frequencies were evaluated in Equation (5). The gripping compression was kept constant at the fixed ends using a proper torque wrench.

$$f_{sh} = \frac{f_c - f_e}{f_c} \times 100 \quad (5)$$

where, f_{sh} is the relative shift of frequency (%) defined as a function of experimental frequency f_e and calculated fundamental frequency f_c.

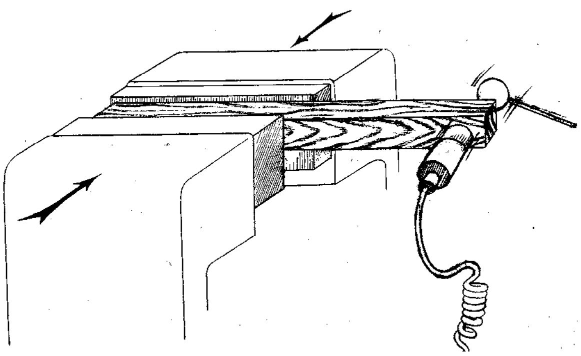

Figure 2 Schematic view of the setup for free flexural vibration of a fixed-free bar test. Sound recording and hammer impact at free end of the bar
Slika 2. Shematski prikaz uzorka pričvršćenoga u konzolu za određivanje vibracije savijanja. Pobuđivanje uzorka i mjerenje zvuka obavljeni su na kraju slobodnog kraka konzole

The specimen heights decreased stepwise from 20 to 18, 16, 14, 12, 10 and 8 millimeters and the above-mentioned evaluations were replicated thoroughly.

The gyration radius was divided into free lengths and correlated with the frequency radius corrected for shear and rotary motion, obtained from calculated frequency shifts and compared to the Timoshenko's correction curve (Fig. 1, n=1).

Apart from Timoshenko's correction, another equation was proposed to predict the frequency shifts in terms of free length (l) and height (h) of the beams (to compensate the effects of shear deflection and rotary motion). Then, the dynamic flexural moduli of the specimens were evaluated using recalculated frequencies of fixed-free beams before being compared to previous reference moduli of free-free flexural vibration.

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Frequencies corrected for shear and rotary motion obtained from the calculated frequency shifts were plotted as the radii of gyrations divided into free lengths in Fig. 3.

Comparison between the fitted curve in this particular study (Fig. 3) and Timoshenko's correction curve (Fig. 1, n = 1) shows some similarities and differences. The studied interval was too limited to reject Timoshenko's correction method for this particular timber material. However, it should be noted that, as shown in Fig. 3, when the root of Equation (2) decreased to smaller values ($\sqrt{\alpha}$ <0.005), the frequency correction factor hardly approached 1.0. So, the effects of shear force and rotary motion were not compensated yet. So, the Timoshenko's correction curves were proposed based on the dynamic behavior of isotropic materials, for example, steel, aluminum or magnesium (Harris 2002). However, some deviations from this proposition could be initially expected for an anisotropic/orthotropic material.

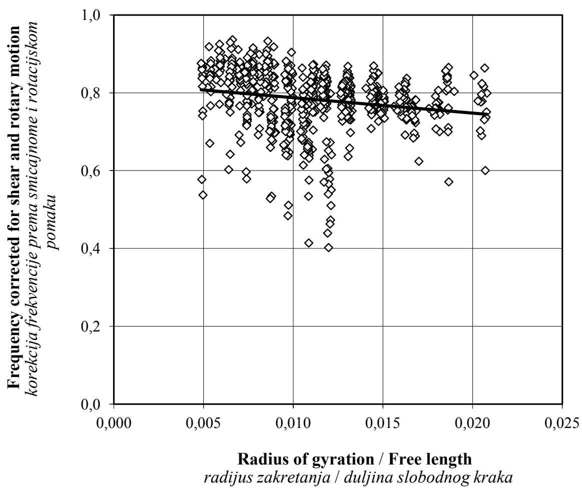

Figure 3 Fundamental (n = 1) frequency corrected for shear and rotary motion versus radius of gyration divided by free length ($\alpha^{0.5}$) in studied fixed-free specimens
Slika 3. Prirodna (n = 1) frekvencija korigirana prema smicajnome i rotacijskom pomaku u ovisnosti o kvocijentu radijusa okretanja i duljini slobodnog kraka uzorka konzole

To propose an equation to compensate for the effects of shear deflection and rotary motion (in terms of free length, l, and height, h, of the beams), other than Timoshenko's correction proposition, the frequency shifts were plotted against l/h ratios in Fig. 4. The correlation was statistically significant at p-value<0.01 despite a low R^2. Frequency shifts decreased with increases in l/h ratio.

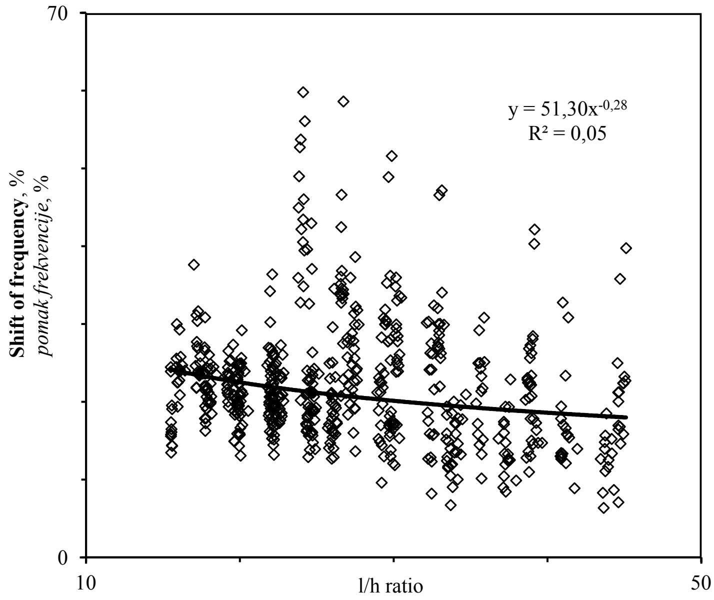

Figure 4 Frequency shifts versus *l/h* ratio of specimens in the stepwise scenario
Slika 4. Pomak frekvencije u odnosu prema kvocijentu duljine slobodnog kraka i visine uzorka (*l/h*)

To check the properties of the fitted curve, the recalculated fundamental frequency of fixed-free data, f_{re} (Hz), was obtained from experimental frequency, f_e (Hz), and recalculated frequency shifts, f_{resh} (%), by Equations (6) and (7).

$$f_{resh} = 51.3 \cdot \left(\frac{l}{h}\right)^{-0.28} \tag{6}$$

$$f_{re} = \frac{f_e}{1 - f_{resh}} \tag{7}$$

Recalculated frequencies in fixed-free conditions versus initially calculated fixed-free values from reference free-free data, f_c, are plotted in Fig. 5. This equality of the data calculated from reference and experimental values with highly powerful correlation coefficient implies that the estimated curve equation can be applied to compensate for the effects of shear deflection and rotary motion. The evaluated correlation coefficient was statistically significant (at $p<0.01$) in cases when the equality of the vertical and horizontal data was confirmed by *t*-test as well as when these data were seen in trend line equation (Fig. 5).

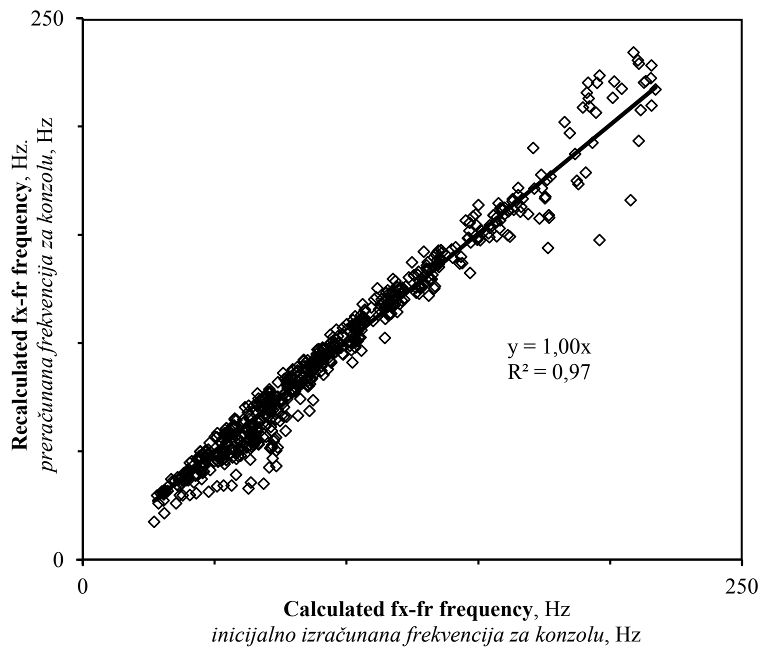

Figure 5 Recalculated frequencies versus innitially calculated frequencies in fixed-free condition
Slika 5. Odnos preračunane frekvencije i inicijalno izračunane frekvencije za sustav konzole

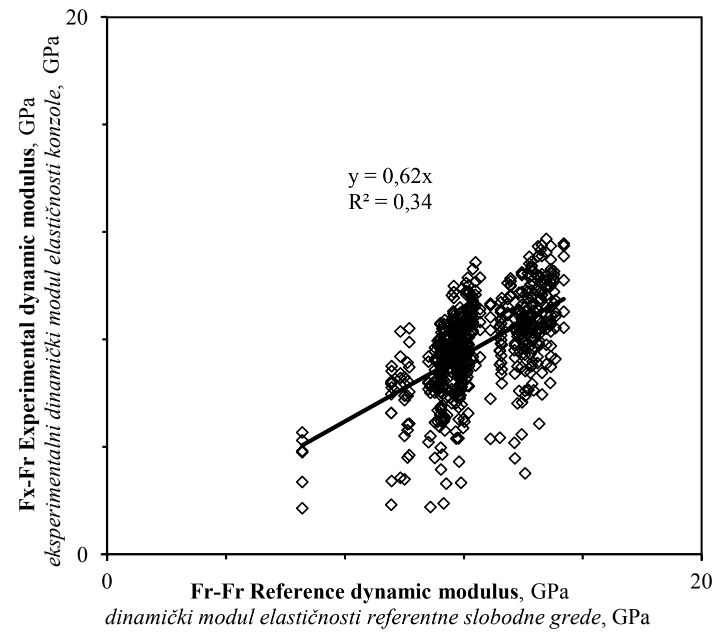

Figure 6 Experimental unmodified fixed-free versus reference free-free dynamic modulus
Slika 6. Odnos eksperimentalnoga dinamičkog modula elastičnosti između nepromijenjene konzole i referentne slobodne grede

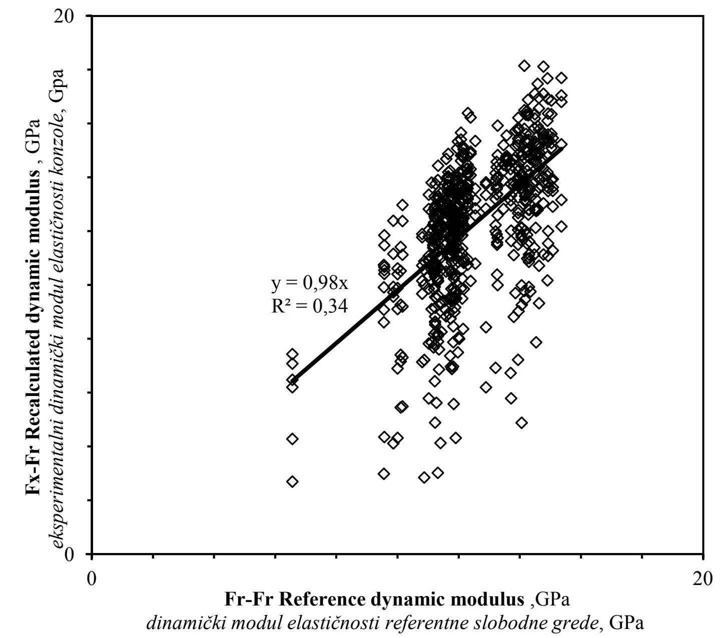

Figure 7 Recalculated fixed-free versus refernce free-free dynamic modulus
Slika 7. Odnos preračunanoga dinamičkog modula elastičnosti konzole i inicijalnog modula elastičnosti slobodne grede

The potential for modification of fixed-free frequency made in Equation (6) would be a significant advancement if it could estimate the dynamic modulus of elasticity as accurately as the reference free-free data. Due to inevitable uncertainties in wood, the correlation coefficient between raw unmodified fixed-free and reference free-free moduli was initially insignificant. However, fortunately, it was statistically significant even at $p<0.01$ (Fig. 6). So, the fixed-free bar in a wide range of *l/h* ratios, with a correction coefficient, enables us to estimate the actual dynamic modulus of elasticity of wood. This correction coefficient might be the one given by Equations (6) and (7), which was applied to experimental fixed-free raw data.

The unmodified experimental moduli in fixed-free condition versus refernce free-free dynamic modulus of elasticity values in this particular study are plotted in Fig. 7. The fixed-free beam for the proposed correction method and Timoshenko's proposition alike were successful in estimating the actual dynamic modules of elasticity, in cases when the equality of the vertical and horizontal axis data was confirmed by t-test; however, the fitted trend line showed this equality. The correlation coefficient was almost low but significantly equal to initial observations of raw and unmodified data. So, the proposed modification method rarely affected the validity of the natural and inherent correlations.

4 CONCLUSION
4. ZAKLJUČAK

Considerable influence caused by shear deflection and rotary motion in fixed-free flexural vibration make the modulus of elasticity hardly obtainable in flexurally-excited beams with similar boundary conditions. Timoshenko proposed a set of curves to correct the fixed-free modal frequency in terms of radius of gyration and free length for isotropic materials such as steel, aluminum or magnesium. A new correction method was proposed and evaluated for timber fixed-free beams with a proper variety of *l/h* ratios. It was concluded that for fixed-free flexural beams the following applied:

- The effect of shear deflection and rotary motion for fixed-free timber beams decreased as *l/h* ratios increased, although it would hardly be noticeable, even in some *l/h* ratios larger than 56.
- Shift of natural frequency of a timber rectangular fixed-free beam in flexural vibration could be evaluated by Equation (6), where the *l/h* ratios ranging from 14 to 59 were tested for suitability.
- The correlation coefficient between experimental and calculated fixed-free frequency was very high (0.97) but the correlation coefficient of experimental and calculated modulus of elasticity values was a bit lower (due to lots of uncertainties related to wood); however, their equality was significantly confirmed even at p-value<0.01. The researcher, therefore, decided to call it an "estimation" of dynamic modulus of elasticity in fixed-free flexural vibration. It would be replaced with "evaluation" when obtaining more evidence from further studies.
- For future studies, it is suggested to extend the frequency correction method to ring-porous and diffuse-porous hardwoods with somewhat different beam dimensions, from ice-cream size to the usual commercial timber cross sections.

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A Method and Device for 3D Recognition of Cutting Edge Micro Geometry

Metoda i uređaj za 3D prikaz mikrogeometrije rezne oštrice

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ABSTRACT • *A very useful method was successfully applied in the investigation of tools for machining wood and wood based composites. It allows scanning of the cutting edge micro geometry in three dimensions and reproducing it in a virtual space as a 3D surface. The application of the method opens new possibilities of studying tool wear by scanning, including the calculation of volume loss and other analysis of tool wedge geometry along and perpendicularly to the cutting edge. Effectiveness of the method and scanner were successfully verified by a reference ESEM (Environmental Scanning Electron Microscopy) method.*

Keywords: *cutting tool wear, 3D scanner, micro geometry*

SAŽETAK • *Vrlo korisna metoda skeniranja uspješno je primijenjena za istraživanje alata za obradu drva i kompozita na bazi drva. Metoda omogućuje skeniranje mikrogeometrije rezne oštrice u tri dimenzije i ponovni prikaz u virtualnom prostoru kao 3D površina. Primjena metode otvara nove mogućnosti istraživanja trošenja alata skeniranjem, uključujući izračun volumena gubitka materijala trošenjem alata ili druge analize geometrije alata uzdužno ili okomito na reznu oštricu. Učinkovitost metode i skener uspješno su verificirani uz pomoć ESEM (Environmental Scanning Electron Microscopy) metode.*

Ključne riječi: *trošenje alata za rezanje, 3D skener, mikrogeometrija*

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1 INTRODUCTION
1. UVOD

The final quality of machining of wood and wood based composites (WBC) depends on many factors, which may be grouped into 4 categories: machined material (including its orientation), cutting conditions (cutting situation, cutting speed, feed speed, feed per tooth, uncut chip thickness, etc.), machine and tool. All these factors (including tool quality) have to be optimal in order to obtain satisfying surface and edges of a material. Construction of a standard rotary tool is based on a tool body supporting one or more cutting edges, regardless whether the tool is a compound assembly or the cutting edges are shaped directly from the tool's body. A tool's body has to be stiff enough to ensure proper positioning of cutting edges subjected to stresses, to be well balanced statically and dynamically, to have room for chips produced during cutting in order to remove them out of the cutting zone, to have no run-out clamping system, etc. Supposing that the tool's body fulfills all these demands and the geometry of teeth is properly selected (e.g. clearance, rake, flank clearance angles), there is one more, very important, parameter influencing any kind of wood or WBC machining – micro geometry of tool tip – particularly its sharpness.

A sharp tool has a positive influence not only on machined surface geometry, but also on reducing cutting forces, decreasing energy consumption, minimizing vibrations and noise level. On the other hand, a worn tool – particularly in case of extreme wear – has a great impact on the surface quality and on machine dynamics (Paris and Peigne, 2007). Since sharp tools are highly desired by industrial tool users, it has been of highest interest to increase the life-span of tools (time of usage ensuring quality demands). It is crucial, therefore, to understand the process of tool blunting. This issue has already been studied by several researchers. Ramasamy and Ratnasingam (2010) for example, pointed out that tool wearing might be caused by: gross fracture or chipping (catastrophic) abrasion, erosion, micro fracture, electrochemical corrosion and oxidation. However, depending on the process, tool and machined materials, the rate of each can vary. In consequence, new, more wear-resistant cutting tool materials and/or coatings and bulk materials are introduced into tool production (Sheikh-Ahmad and Bailey, 1999). These include new generation tungsten carbides, Polycrystalline Diamond, Diamond Dispersed Cemented Carbides, and various PVD/CVD coatings, among others. The development requires, however, good techniques for recognizing the tool wear in order to verify the effectiveness of improvements.

It has been the interest of many researchers for years to recognize the tool wear during wood machining. Klamecki (1979) states that: "The change in the cutting tool with use has generally been monitored in two ways, by observing the change in the edge geometry, and by observing changes in the forces acting during cutting". He also notices that some authors have used other measures of tool dulling e.g. time needed to plane a given length of wood while applying a constant feed force, or the size of sawdust chips used as an indicator of tool wear. Even if the above statement was still valid, it should not be forgotten than the generated surface quality is probably the most important among all. It can be concluded that all methods of tool wear measurement may be divided into: direct and indirect.

1.1 Direct methods
1.1. Direktne metode

The most obvious way of controlling the tool wear is a direct measurement of tool geometry. It has several disadvantages: time-consuming duration (disassembling, measuring and assembling a tool or a blade) and difficulties in assembling the tool (after measurement) in exactly the same position. This disqualifies direct methods as real time (or on-line) measurements. On the other hand, these provide objective and absolute wear results (Bonamini *et al*., 1999). Three techniques of direct tool tip geometry measurement are usually used: contact, optical and SEM.

Contact methods rely on scanning the cutting edge by means of tip or wedge type stylus moved along or perpendicularly to achieve tool wedge profile (Miklaszewski *et al*., 2000, Novacek and Novak, 2006). A 3D representation of a tooth can be obtained by repeating scanning profile by profile and by combining them together.

A non-destructive silicone cast cross-section method is another alternative for reproducing the cutting edge profile in the contacting mode (Miklaszewski *et al*., 2000; Sheikh-Ahmad and Bailey, 1999). It is, however, rarely used due to rather intensive preparation work of casts and significant time necessary for scrutinizing data.

Optical approach for scanning cutting edge geometry has several varieties. In the simplest setup, optical microscope is used to observe the tool tip. If the microscope is equipped with a camera, it is then possible to capture the image and afterwards to analyze by means of image processing methods (Aknouche *et al*., 2009; Kowaluk *at al*., 2009; Lemaster *at al*., 2000a; Nordström and Bergström, 2001). Putting Vickers indentation marks (or surface scratches) on the observed face as a spatial reference proved to be useful. The progress of the distance between the mark and the cutting edge might then be used as an indicator of wear rate (Bonamini *et al*., 1999; Ishida *et al*., 2005; McKenzie and Karpovich, 1975). Moreover the measurement does not depend on the initial edge wear as the measuring base is steady.

Kapcia *et al*. (2010) presented a mechatronic system for automatic inspection of circular saw teeth in an off-line manner. The described system has been implemented, based on numerical processing of recorded tooth images, in the automatic vision controller system WKOPTar. The system allows the user to determine up to 32 geometrical parameters for one tooth. However, the direct interpretation of physical parameters is sometimes partially limited by the software applied because the same parameter might have different meaning (Wasielewski and Orlowski, 2005).

Methods using laser light are also considered optical methods. Some trials have been undertaken to acquire a measure of tool geometry in-situ on the rotating spindle: Ohuchi *et al*. (2003) have used laser curtain instrument for detecting outer diameter of a router bit. They successfully compared the results with a stylus method.

Several optical methods giving 3D surface models of a cutting edge zone have been previously considered by Sandak *et al*. (2011). Laser micrometric scanner, laser displacement sensor, laser line triangulation, shadow triangulation and depth-from-focus have been analyzed to verify their potentials.

Scanning Electron Microscope (SEM) is used to measure the tool wear. In many cases (Fuchs *at al*., 2005; Okai *et al*., 2006; Sheikh-Ahmad and Bailey, 1999) SEM is used in the same way as an optical microscope to make high resolution images, which are then subjected to geometry measures or simply qualitative analysis. Compared to optical microscopy, SEM has the great advantage of having a much higher depth of focus, which is favorable for 3D reconstruction by stereovision. Stereovision is at the moment one of the most precise methods of reproducing tool tip micro geometry into a 3 dimensional virtual space. SEM techniques have a great structural disadvantage though: limited chamber space that often leads to destroying the tool by breaking its teeth, making it unusable for further monitoring of tool wear.

Regardless of the measuring method, different parameters are used by authors to quantify tool wear.

McKenzie and Karpovich (1975) have used many parameters in order to provide a wide spectrum of tool blunting related to cutting forces. None of their parameters was linearly related to the cutting forces. Porankiewicz *et al*. (2005) noticed that, in wood cutting, edge recession on the clearance face (VB_F) was the most intensive of all measured parameters in their experiment. This was confirmed by Sheikh-Ahmad and Bailey (1999) based on replica cross-section. Sheikh-Ahmad *et al*. (2003) have used nose width – wear land measured in a surface perpendicular to the tool angle bisector. Alternatively, a cutting edge rounding (tool tip radius) might be used for the quantification of tool wear (Bonamini *et al*., 1999). Most wear measures proposed by authors are the result of the available two dimensional tooth edge profiles.

Recent developments in the area of 3D scanning of cutting edges have opened new possibilities of developing other tool wear indicators than those presented above. Some of 3D scanning methods have been already applied in metal cutting tools. Niranjan Prasad and Ramamoorthy (2001) have successfully used simplified stereometric imagining method to detect tool crater wear. Durazo-Cardenas *et al*. (2007) used Taly-Surf surface profilometer based on white light interferometry to obtain 3D representation of tool wear. This method is, however, intended for more or less flat surfaces and does not seem suitable for tool wedges.

1.2 Indirect methods
1.2. Indirektne metode

A number of indirect methods of tool wear recognition have been developed in parallel to direct measurement of cutting edges geometry, especially within on-line applications. From practical point of view, it is not the geometry of the tool that matters but the effect it makes on the process (quality of generated surface, energy consumption, sound intensity, etc). For this reason, as well as because of online possibilities, indirect measures of tool wear seem to be a very attractive alternative to adaptive control of cutting processes.

So far, besides cutting forces that were considered by many researchers (Aknouche *et al*., 2009, Klamecki, 1979), several other physical effects of cutting have also been researched in order to predict the tool wear. These include energy consumption, vibrations (Lemaster *et al*., 2000a, 2000b), acoustic emission (Lemaster and Tee, 1985; Tanaka *et al*., 1992), and temperature of machined surface (Sokolowski and Gogolewski, 1999). It should be emphasized though, that in most cases for the calibration of indirect measurement systems, series of data of the cutting tool micro geometry are required as a reference.

Therefore, the goal of this work was to develop, based on previous studies (Sandak *et al*., 2011), a dedicated methodology and device for virtually reproducing the cutting edge form and for providing information about its micro geometry in three dimensions. Another objective was to develop an algorithm for automatic determination of selected tool wear parameters.

2. MATERIAL AND METHODS
2. MATERIJAL I METODE

2.1 Three dimensional reproduction of the cutting edge
2.1. Trodimenzionalni prikaz rezne oštrice

The shadow line sectioning (triangulation) was chosen for the present study from many techniques mentioned above. It was previously found (Sandak *et al*. 2011) to be the most reliable of all tested methods of tooltip scanning. The method works as follows: a structured light-shadow border (light half plane) is projected on the scanned object at a specific angle and the image of this boundary is observed at the same time from another angle (Fig. 1).

The light-shadow border line represents the object contour. On the flat surface perpendicular to the camera's optical axis, the border appears as a horizontal line. When the surface is moved along this optical axis, the horizontal border line (between bright and dark half-planes) changes its vertical position at the image recorded by the camera. It gives information about the third dimension – depth. The lower the position of the image line (at the present setup), the farther it is located from the camera. If the pattern is projected onto a wedge (e.g. of the tool tip), the border line folds into a double slope hill (Fig. 1 and 3). In that case each

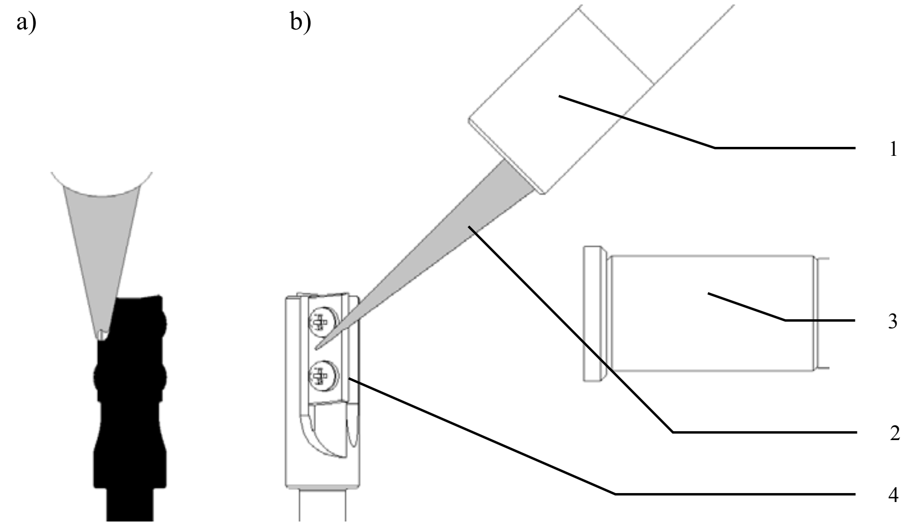


Figure 1 Shadow line sectioning (triangulation) technique: a) the camera point of view: light-shadow border projected on the tool illuminates tool tip (white) and discovers the shape of the cutting edge section b) side view of projector-camera-tool setup. 1) LED projector with lenses, 2) light beam, 3) camera with lenses, 4) inspected tool

Slika 1. Tehnika prikazivanja linije sjene (triangulacija): a) točka gledišta kamere – granica svjetlo - sjena projicirana na alat osvjetljava vrh alata (bijelo) i otkriva oblik presjeka rezne oštrice; b) bočni pogled na sustav projektor – kamera – alat: 1 – LED projektor s lećama, 2 – svjetlosna zraka, 3 – fotoaparat s lećama, 4 – alat

point of the border line may be located on a different depth and consequently the line is not straight anymore. Some more details regarding the principles of triangulation measurement as well as analysis of scanning error have been presented in the previous work of the authors (Sandak, 2007). An example of application of the light-shadow scanner has been presented in the work of Sandak *et al*. (2005).

2.2 Scanner hardware and software
2.2. Hardver i softver skenera

The scanner's hardware was designed and built based on the method and assumptions discussed above. The scanner was configured like a miniature 4 axis CNC machine having motorized three perpendicular axes *X*, *Y* and *Z* and one rotational *C* axis allowing the rotation of tool around *Z* axis (Fig. 2). An inspected tool (5) was fixed in a universal, self-centering chuck (3) mounted on rotary stage of *C* axis (2). This set was then fixed on two-directional *X*-*Y* moving table (1) with 100×100 mm movement range. The core of the ToolScan system – an optical unit – was attached to the *Z*-axis linear table (4) placed vertically. The optical system included a camera (6) and projector (7). The camera was monochromatic CCD 2/3" with the resolution 2448×2050 pixels coupled with low distortion macro lenses. The source of light (3W LED red light projector) was equipped with the light-shadow pattern and telecentric lenses ensuring superior quality and simultaneously low distortion projection. The angle between optical axes of the projector and the camera was 45°. Both positioning and optical systems were put in a darkroom housing to avoid external light to interfere with the projected one. Selected functional parameters of the scanner are shown in Table 1.

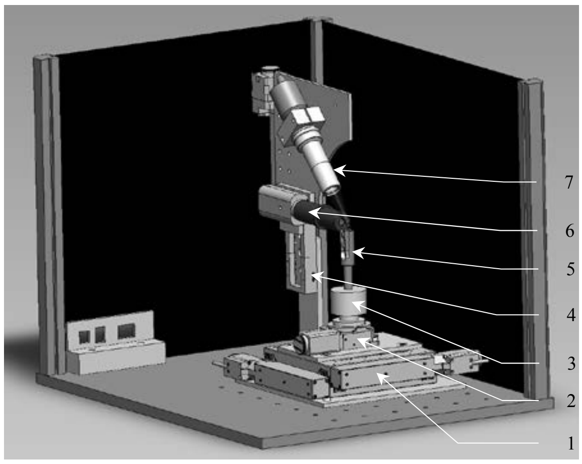


Figure 2 Design of ToolScan scanner: 1) *XY* moving stage, 2) rotary stage, 3) self-centering chuck, 4) *Z* moving stage, 5) tool under inspection, 6) camera, 7) light projector

Slika 2. Dizajn skenera *ToolScan*: 1 – *XY* pokretno postolje, 2 – rotirajuće postolje, 3 – samocentrirajuća stezna glava, 4 – postolje pokretno u smjeru osi *Z*, 5 – alat, 6 – kamera, 7 – svjetlosni projektor

The process of scanning is automatic; however before starting it, a few parameters have to be set up. First of all, the inspected cutting edge has to appear in the camera field of view and both clearance and rake faces should be visible. This is done with help of the manipulation panel. Then the exposition time has to be chosen, depending on reflective behavior of the teeth material. Diamond tipped tools need generally shorter exposition time than HM or HSS tools. Finally, the length of cutting edge to be scanned and the scanning resolution have to be defined.

Table 1 Basic characteristics of positioning and optical systems
Tablica 1. Osnovna obilježja pozicioniranja i optičkog sustava

	Range / *Raspon*	**Resolution** *Rezolucija*
X axis	100 mm	0,3 µm
Y axis	100 mm	0,3 µm
Z axis	100 mm	0,125 µm
C axis	360°	4,5”
Camera field of view – adjustable *Područje vidnog polja kamere - prilagodljivo*	2,9x2,2 ÷ 126x102 mm	1,2 ÷ 50 µm

In the present configuration, 3D scanning requires a set of images to reproduce the map of the tooth tip surface in a virtual space. For this reason, the camera and the tool have to move along the cutting edge. While moving, the camera is triggered by the encoder with the frequency depending on the movement speed and selected resolution. As a result of scanning, the set of images is acquired and subjected to further analysis.

The calculation algorithm is divided into three main tasks, executed sequentially:

- analysis of the single image providing the profile of the tool
- conversion of the two-dimensional (2D) coordinates into the three-dimensional (3D) space and calculation of the angles required for proper aligning of the tool in 3D space
- calculation (in 3D space) of the missing points of the surface model, based on modified Shepard algorithm and final image post-processing

Analysis of the single image acquired from the scanner (Fig. 3a) is the most important stage of the whole image processing algorithm due to its impact on further processing steps.

Before the contour extraction is performed, the raw image is preprocessed using the following workflow:

- removal of the fine-grained noise using the erosion-dilation and median filtering
- image smoothing by the Gaussian-based filtering
- actual contour extraction based on Canny filter (edge detector) combined with the FloodFill algorithm

This procedure provides a few candidate contour curves (usually less than 5), from which only one is selected. The contour selection procedure is based on: its position in the image, size and shape (using a predefined tool shape). The selected contour is then corrected by using the artifacts removal procedure. The detected contour – the final result of this stage of algorithm – is presented in Fig. 3b.

2.3 Conversion of the two-dimensional coordinates into the three-dimensional ones and tool alignment in 3D space
2.3. Konverzija dvodimenzionalnoga koordinatnog sustava u trodimenzionalni i smještanje alata u 3D prostor

The coordinate system, used during the analysis, is presented in Fig. 4.

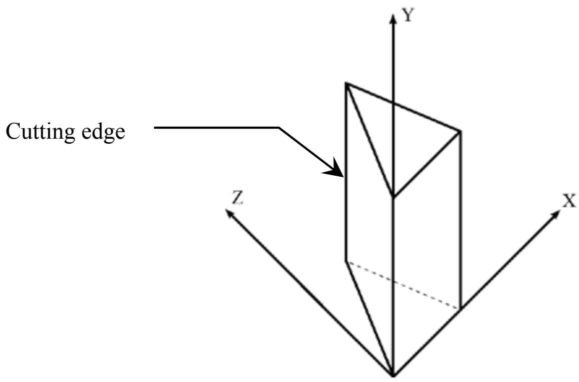


Figure 4 Coordinate system used for calculation
Slika 4. Koordinatni sustav primijenjen za izračun

a) b)

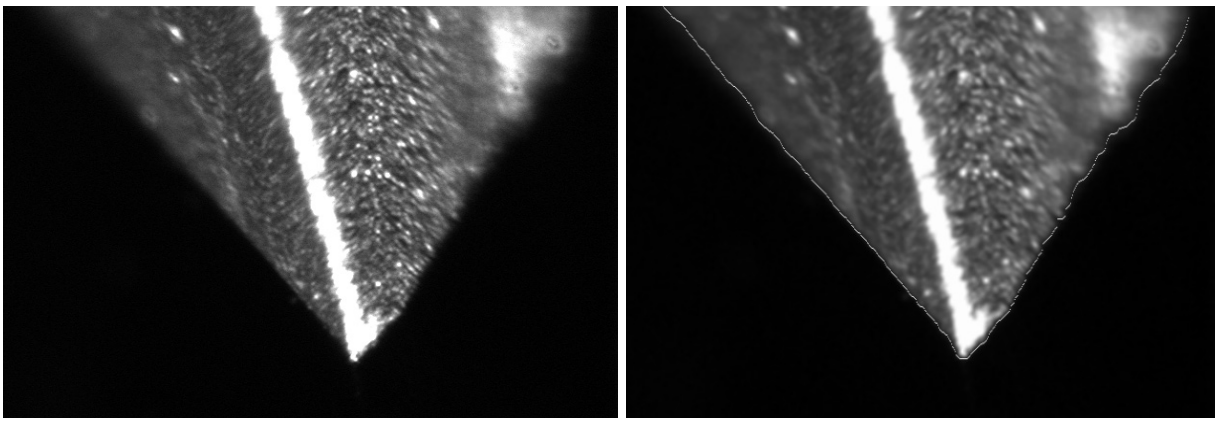


Figure 3 Image of illuminated tool: a) raw and b) with contour detected
Slika 3. Slika osvijetljenog alata: a) izvorno, b) s označenim konturama

The contours (one for every image, in 2D space), as the result of the previous stage, are converted into the point cloud description in the 3D space. The input data – contours – are defined in the 2D space related to the pixel coordinate system used in the images. This conversion is governed by the following rules:

$$p3D_x = C_1 \cdot p2D.x \qquad p3D.y = C_1 \cdot p2D.y + C_2 \cdot i \qquad p3D.z = C_1 \cdot p2D.y \cdot \tan\alpha$$

where:
p3D coordinates of the point (μm) from point cloud in 3D space
p2D coordinates of the point (pixel) from the contour extracted from the image of the number num image
C_1 coefficient defining the scale of mapping (μm/pixel)
C_2 coefficient defining the Y-axis distance between consecutive scanned images analyzed in the previous stage of the algorithm (μm)
i number of image
α angle of the projector axis (in present setup 45°)

If the alignment of the cutting edge is not perfect when compared to optical system during scanning, which may be caused by the tool itself or its fixing in the chuck, a virtual rotation of the point cloud is performed. This is done by detection of rake and clearance faces in the unused part of the tool. Using these two planes, the theoretical cutting edge is determined and the whole model is aligned to make the edge perpendicular to XZ plane.

2.4 Calculation (in 3D space) of the missing points of the model, based on modified Shepard algorithm and final image post-processing
2.4. Izračun (u 3D prostoru) točaka modela koje nedostaju na temelju Shepardova algoritma i konačno procesuiranje slike

The process of defining the final model of the scanned tool usually requires more data than is contained in the point cloud defined in 3D space. The missing points in the cloud are determined with help of the modified Shepard's method – the multivariate interpolation method for the scattered, irregular set of points. This method, in order to compute the parameters of the missing point, uses only the nearest neighbors within the R-sphere of this point instead of using the full data set. The modified Shepard's method requires an efficient spatial search data structure. In the present algorithm the kd-tree structure has been implemented. In the algorithm, the FLANN library (available under the BSD license) has been used for the implementation of the kd-tree structure.

The numerical experiments showed that the final model of the scanned tool, based on the supplemented point cloud, exhibits numerous artifacts, whose origin lies amongst others in the interpolation procedure. In order to minimize the number of artifacts and to weaken their intensity, the smoothing procedure is applied as the last step of the algorithm. This procedure is based on the set of Gaussian filters.

After the surface model of the tooth tip is created, it can be visualized using any 3D data analyzing software. Examples of the obtained models of tool's cutting edges visualized with Gwyddion software are shown in Figure 5.

a)

b)

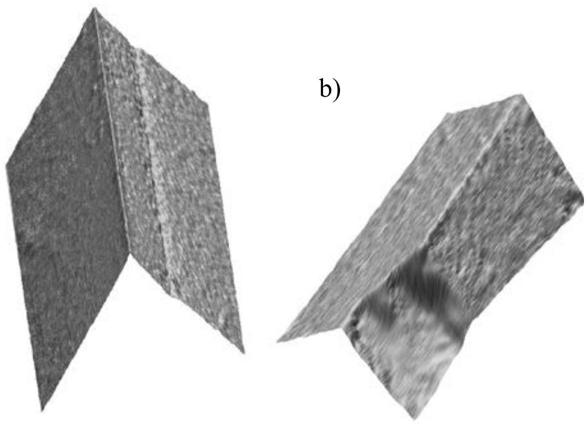


Figure 5 Surface models of diamond (PCD) cutting edges acquired with ToolScan: a) sharp insert on carbide base, b) catastrophic wear of tool (crushed)
Slika 5. Modeli površine dijamantnih (PCD) reznih oštrica snimljenih ToolScanom: a) oštar umetak na bazi karbida, b) katastrofalno trošenje alata (lom)

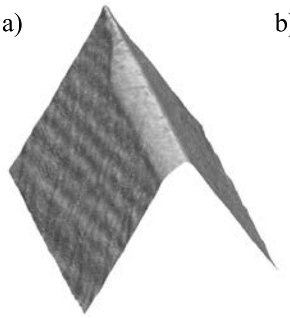
With these models, it is also possible to analyze the wear parameters. As mentioned above, most of widely used parameters intended to describe the tool wear are based on two dimensional data i.e. profiles of tool wedges. It is also possible to achieve such a profile from 3D model obtained by scanning. The digital nature of data facilitates the calculation and measurement of any tool wear parameter: cutting edge recession on the clearance and rake face, radius of rounding, nose width or even the volume of material removed from the tool (difference between sharp and worn wedge). Additionally, it is feasible to evaluate the volume of tooth tip loss along the cutting edge during scanning, assuming that profiles are extracted by sectioning the 3D surface with the planes perpendicular to the theoretical cutting edge.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

A new hardware-software system ToolScan for 3D scanning of tool tip micro geometry was constructed within the framework of this project. The instrument possesses a great potential for tool wear inspection. However, it was crucial to confirm its functionality and accuracy. In order to verify ToolScan abilities, a comparative investigation was performed on cutting edges of changeable tool insert. One of its parts was used to machine 120 meters of MDF board cutting, the other – unused part was considered sharp. The zone containing both used and unused cutting edges (as well as transition between them) were scanned with two 3D methods: the shadow triangulation used in ToolScan and reference stereoscopic ESEM method, being at the moment one of the most precise tool inspection methods. For this work an ESEM XL 30 from FEI was used for the SEM-images with commercial software MeX® from Alicona Imaging GmbH for stereography.

To demonstrate the shadow scanner performance and accuracy, the surface models (3D maps) generated by both methods are presented in Figure 6.

a)



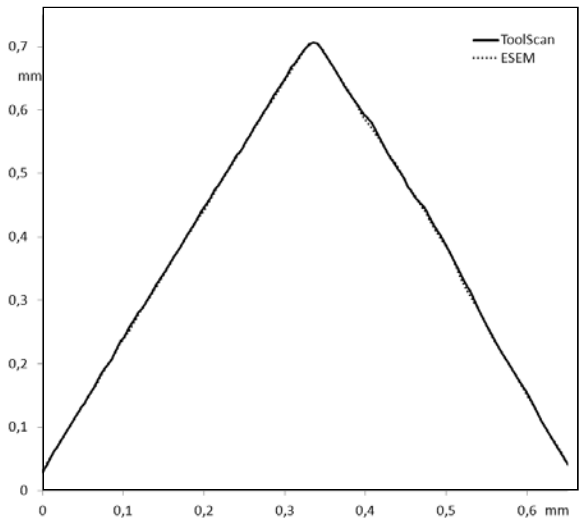
b)

Figure 6 Surface models of sharp-to-blunt transition (c.a. 1mm x 1mm x 1mm) of the investigated tool after 120 m of cutting: a) performed by ToolScan, b) performed by reference ESEM method
Slika 6. Modeli promjene površine alata od oštre do tupe (oko 1mm x 1mm x 1mm) nakon rezanja 120 m u duljinu: a) dobiven uz pomoć ToolScana, b) dobiven ESEM metodom

Next, they were sectioned with a plane perpendicular to theoretical cutting edge at the same position for both models. In this way two comparable profiles were found for worn zone and two for sharp zone, showing the rounding at the corresponding position of the edge (Fig. 7). Additionally, longitudinal profiles of the tool were acquired at the angle bisector plane, indicating the wear along the cutting edge (Fig. 8).

Figure 7 shows that both methods provide very comparable results. It should be noticed, though, that for ToolScan method some artifacts occur in the defocused zone of the images. In the focused zone small, bright particles are recognized as they are, but when moved into defocused zone, meaning fortunately that they are away from the interesting tool tip zone, they become no brighter but much bigger. When acquiring tool profile from images containing such a problem, the artifacts visible in Figure 7b show up. For sharp tool, it is feasible to fit the circle to the tool tip (R=10 µm), however the shape of worn insert tip does not allow to do it properly. This approach seems to have low reliability as a tool wear indicator in the present case.

a)



b)

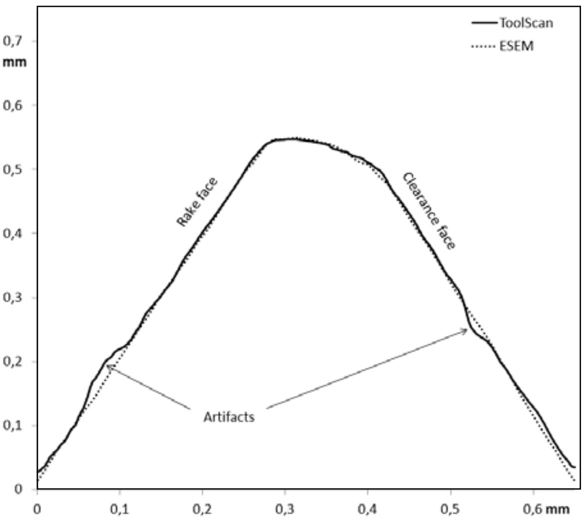


Figure 7 The carbide cutting edge rounding of: a) unused part of tool (tip radius R=10 µm), b) 120 m of MDF cutting
Slika 7. Zaobljenje karbidne rezne oštrice: a) neupotrijebljena oštrica (radijus zaobljenja R = 10 µm) , b) nakon piljenja MDF ploče duljine 120 m

Figure 8 shows that both methods recorded the transition of sharp-to-blunt zones, however, the profiles are not identical. Curves acquired with ToolScan are relatively "smoother". This is because the light-shadow border used in ToolScan is not perfectly sharp and therefore it works as a smoothing filter.

Even if the edge recession of ~80 µm was equal for both methods, the difference between profiles of both methods at the sharp-to-blunt transition zone would be visible. It might be explained by the fact that the optical properties of the scanned material significantly affect the accuracy of scanning. The light reflected from the slope area (passing from sharp to blunt) brightens the cutting edge and seemingly moves the shadow border higher compared to the situation when the measured surface is not polished. The estimation error is in this case at the level of ~10 µm.

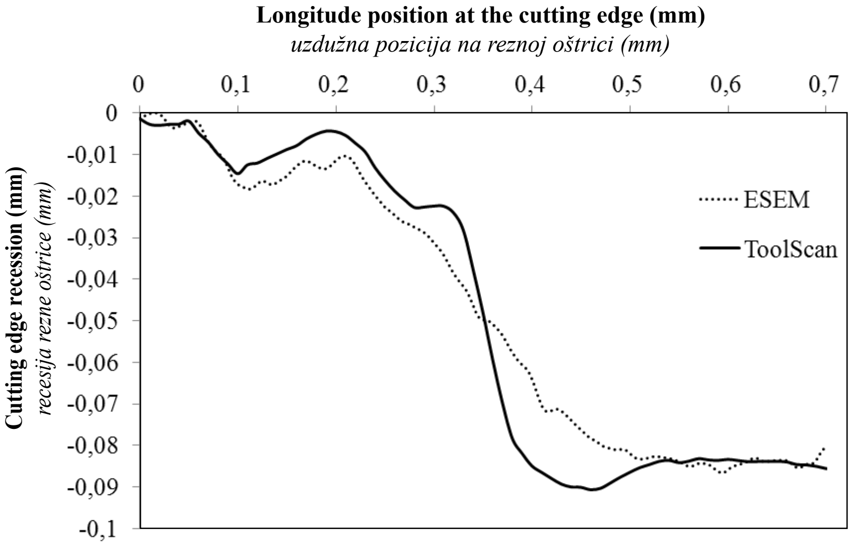


Figure 8 Longitude profile of cutting edge after 120 m of MDF cutting
Slika 8. Uzdužni profil rezne oštrice nakon duljine piljenja MDF ploče 120 m

4 CONCLUSIONS
4. ZAKLJUČAK

A new method (both hardware and software) for three dimensional scanning of cutting tools micro-geometry has been developed within the framework of this project. It has shown a great potential in tool wear investigation, resulting in a 3D surface model of the investigated tool with micrometric accuracy comparable to the stereoscopic ESEM method. It is a fully non-destructive method, which allows multiple, fast, intermediate scanning e.g. during the determination of tool wear curve.

Although the shadow scanner performance encourages additional tests, it must be mentioned that, due to the optical nature of measurement, it is sensitive to the change of reflective properties of scanned materials. Moreover, it requires careful cleaning of tools and removing dust particles in order to avoid dirt artifacts. It is possible to adjust scanning parameters to the given tool material, but automating this procedure is not easy.

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Impact of Economic Crisis on Changes in Motivation of Employees in Woodworking Industry

Utjecaj ekonomske krize na motivaciju zaposlenika u tvrtkama drvne industrije

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ABSTRACT • *The paper deals with the motivation of employees of a woodworking enterprise and analyses the level of individual motivation before (2004) and after the economic crisis and its effects in Slovakia (2012). The aim of the paper is to identify the most important motivation factors for employees and to consider the impact of financial crisis on the change in perception of individual motivation factors and their economic and social impact on employees. A questionnaire, as a method of inquiry, was used to acquire relevant data. Descriptive and testing statistics were used for data processing. Significance level p was computed for individual motivation factors for the year 2004 and 2012 by means of T-test. The objective of this paper is to define significant change of average rate of individual motivation factors and to compare the order of importance of motivation factors before and after the economic crisis. Based on our research it can be stated that the world economic crisis has no impact on the level of employee motivation in the selected enterprise.*

Key words: *motivation, motivational programme, changes of motivation, economic crisis, T-test*

SAŽETAK • *Autori se bave motivacijom zaposlenih u tvrtkama za preradu drva i analizom razina pojedinih motivacijskih čimbenika prije početka ekonomske krize (2004) i nakon što je ona zahvatila Slovačku i postala ozbiljna. Cilj rada je definirati najvažnije čimbenike motivacije zaposlenika te utjecaj ekonomske krize na promjenu važnosti pojedinih motivacijskih utjecaja, pri čemu je naglasak na ekonomskim i socijalnim čimbenicima. Da bi se prikupili relevantni podaci primijenjena je metoda anketiranja odnosno upitnika, a za obradu i testiranje podataka poslužila je statistika. Pri korištenju T-testa izračunavana je značajna razina p za pojedine motivacijske čimbenike u razdoblju od 2004. do 2012. godine. Rezultat istraživanja jest definiranje značajne razlike srednje vrijednosti pojedinih motivacijskih čimbenika i usporedba njihovih vrijednosti prije i nakon nastanka ekonomske krize. Na temelju ovog istraživanje može se utvrditi da ekonomska kriza nema utjecaja na razinu motiviranosti zaposlenika u promatranim poduzećima.*

Ključne riječi: *motivacija, motivacijski program, promjene u motivaciji, ekonomska kriza, T-test*

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1 INTRODUCTION
1. UVOD

Market globalisation, lack of qualified workforce and financial crisis present permanent pressure on the enterprise management, which must be focused on developing a competitive strategy as well as on determining and implementing crisis management to keep the enterprise going. The enterprise can have high technology, dispose of vast financial resources and precious information but only qualified and skilled employees will make decisions and ensure success and competitiveness of the enterprise (Hitka and Sirotiaková, 2011).

As a result of recent changes in the economic structure, i.e. the adaptation of the Slovak economy to market conditions, enterprises pay more attention to man and his personal traits. As the only source of innovation and progress, the employee can use new opportunities, markets and up-to-date technologies. The above mentioned changes can also be observed in the area of woodworking industry (Jelačić *et al*., 2012). Prosperity and enterprise competitive advantage in the market can be ensured by human factor that also determines the operations of the production process, its results and human behaviour. Since the significance of the human factor has been underestimated in the production process management where machines and technology dominate, changes will occur in personnel position and responsibilities and increasing attention will be placed on personal traits as the reaction of enterprises to changed market conditions (Blašková, 2011). Some changes in the area of motivation could be observed in the research conducted in Slovenia and Croatia (Kropivšek *et al*., 2011). When a company wants to be in a position to perform these changes, it is necessary to motivate employees, i.e. to appeal to intrinsic motivation by selected motivational tools and ways. Some methods can be used to manage the period of crisis by means of non-financial rewards of employees – to restructure teams, arrange educational activities within the enterprise, train employees, offer language and IT courses, management training, professional courses, seminars and trainings, and to benefit from some outsourcing tools (Potkány, 2008). Many sports activities and various corporate events can be carried out by the enterprise to improve interpersonal skills, too. It is also important to encourage corporate communication especially towards subordinates. Additional forms of non-financial motivation show employee recognition and appreciation and improve employee empowerment. Selection of non-financial rewards should be made by employees. Another way of employee motivation is self-actualization, which means delegation of some competences and responsibilities. However, employees can also be motivated by changes in the enterprise management system. Benefits and motivation programmes, by which employees can meet their needs of self-actualization or their economic requirements, can also be effective. The employees' potential can be started by effective no-money tools (Vetráková *et al*., 2001).

In the current economic situation, which is influenced by ongoing economic crisis, it is necessary to think about employee motivation in connection to work performance and to analyze this relationship consistently. To do so, it is essential for the enterprise employees to know the motivation factors. Therefore, the aim of this paper is to find out how employees of the selected woodworking enterprise evaluate their job position, how they feel at work and what the structure of their needs is, i.e. to identify their most important motivation factors. Considering the above mentioned factor, i.e. the ongoing economic crisis, the impact of the crisis on changes in motivation of employees in woodworking industry was observed.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

A general questionnaire was used as a tool of inquiry to analyze the motivation factors of employees in woodworking industry. Analysis of the motivation factors of enterprise employees was carried out in the year 2004 and 2012. The analysis was repeated in order to consider the impact of economic crisis on motivation of employees of the selected enterprise. The questionnaire consisted of 30 closed questions (Hitka, 2010). In order to be easily understood, it was created in a simple version for all categories of employees. The questionnaire was divided into two parts. The first part was focused on socio-demographic and qualification characteristics of employees. Information about respondents related to their age, sex, years of work in the enterprise, completed education and job position were acquired. Individual motivation factors were determined and used for acquiring information about characteristics of work environment, working conditions, employee appraisal and reward system, about human resources management, health and social care system and system of employee benefits. Information about employee satisfaction or dissatisfaction, value orientation, relation to work and enterprise or co-workers' relationship were included in the second part of the questionnaire. In order not to affect the respondents, individual motivation factors were ordered alphabetically. The employees could mark each question item with only one of five degrees of importance from the evaluation scale stated in Tab. 1.

Table 1 Scale of importance of motivation factors (Hitka, 2010)
Tablica 1. Ocjena važnosti motivacijskih čimbenika (Hitka, 2010)

5	4	3	2	1
the most important *najvažnije*	very important *vrlo važno*	medium important *srednje važno*	slightly important *manje važno*	Unimportant *nevažno*

Questionnaires were evaluated by the programme STATISTICA 7. For describing the sets (the year 2004, the year 2012), descriptive statistics was used. Statistical characteristics, which compressed information about the observed sets into a smaller number of numerical characteristics making easier the comparison of sets, were computed for each motivation factor. Each motivation factor was summarily described by the basic characteristics of size and variability of quantitative features – arithmetic mean, standard deviations and coefficients of variation.

Besides the simple comparison of descriptive characteristic values, testing statistics was used to consider the impact of economic crisis on employee motivation. The purpose of statistical testing was to determine whether the impact of economic crisis caused statistically significant differences in perception of importance of individual motivation factors among enterprise employees. To test the equality of arithmetic means of motivation factors of two basic sets (the year 2004, the year 2012), *T*-test was used. Null hypothesis and alternative hypothesis were tested; they were as follows:

H0: it is supposed that arithmetical means of motivation factors observed in the year 2004 and 2012 are equal and the difference between them, if any, is only caused by accidental score fluctuation, i.e. the economic crisis does not have any statistically significant effect on the change in perception of the importance of motivation factors in the year 2004;

H1: it is supposed that arithmetical means of motivation factors observed in the year 2004 and 2012 are not equal and the difference between them, if any, is not caused by accidental score fluctuation, i.e. the economic crisis has statistically significant effect on the change in perception of motivation factors in the year 2004

To verify the correctness of $H_{0,}$ random variable was used as a test criterion, where t – division with the number of degrees of freedom $n – 1$ in the form (Scheer, 2007):

$$t = \frac{\bar{x} - \mu_0}{\frac{s_x}{\sqrt{n-1}}} \quad (1)$$

At the end of the test, t was compared with $t_\alpha/2;f$, in case $t \leq t_{\alpha/2;f}$, H_0 was accepted and the difference was not considered significant, and on the contrary if $t > t_{\alpha/2;f}$, H_0 was refused at α % level of significance, and the alternative hypothesis H_1 was accepted.

3 RESULTS
3. REZULTATI

Despite the above analysis and recommendations from the year 2004 (after carrying out analysis 1), at present there is no motivational programme in the analysed enterprise. Individual motivation factors are incorporated into collective agreement and especially the following motivation factors: basic salary, further financial reward (extra performance pay, special pay, personal bonus, anniversary and jubilee bonus), job security, work environment improvement, social benefits (transport allowance, meal allowance, holiday entitlement, supplementary retirement savings), education and personal growth.

Basic information about respondents related to their age, sex, years of work in the enterprise, completed education and job position were analysed in the first part of the questionnaire. Due to its length, the evaluation of this part of the questionnaire is not presented in this paper. Individual motivation factors were observed in the second part of the questionnaire. The most important motivation factors from the point of view of employees in the year 2004 are presented in Tab. 2. Based on the obtained mean values, it is possible to say that, from the point of view of employees, the most important motivation factors are the basic salary and further financial rewards. Differences in the obtained mean values of significance level of these factors are negligible (Δ 0.01). Further to the above, it can be stated that the financial motivation (i.e. financial reward) was the best motivation for employees at the time before the economic crisis, too. The survey also showed the fact that job security was also very important for the employees of the analysed enterprise. It can be related with the position of the enterprise. At that time the unemployment rate in the area of the enterprise was 18.1 %. According to motivation theories (Blašková, 2011), employee satisfaction can be increased if the employer pursues a fair social policy and appraisal system. This fact was also confirmed by the above mentioned survey of motivation in the woodworking industry. According to employees of the analysed enterprise, the motivation factors that follow those related to employees rewarding, are – social benefits, e.g. health care and rehabilitation services, housing policy, meal allowance, cultural and community care provided for employees and family members, employee child care, sale of products at discount price and offering loans. It was followed by motivation factors like atmosphere at workplace and good working team, which represent an important role in human life. It means that good atmosphere at workplace and good workplace relations significantly affect the employee satisfaction at work.

Table 2 The most important motivation factors in the year 2004
Tablica 2. Najvažniji motivacijski čimbenici u 2004. godini

S.N.	**Motivation factor** / *Motivacijski čimbenik*	∅
1.	Basic salary / *osnovna plaća*	4.69
2.	Further financial reward /*dodatna financijska nagrada*	4.68
3.	Job security / *sigurnost radnog mjesta*	4.65
4.	Social benefits / *socijalne naknade*	4.57
5.	Atmosphere at workplace / *atmosfera na radnome mjestu*	4.55
5.	Good working team / *dobar radni tim*	4.51
7.	Fair appraisal system / *pošten sustav ocjenjivanja*	4.48
8.	Supervisor' s approach / *supervizorski pristup*	4.45
9.	Opportunity to use own abilities / *mogućnost iskazivanja sposobnosti*	4.33
10.	Prestige / *prestiž*	4.31

In the year 2012, the basic salary remained the most important motivation factor (Tab. 3). It became even more important because of bad economic situation and indebtedness of people caused by the economic crisis. Reduced savings due to rising prices of most consumer goods, and reduced basic salaries following the reduced demand for products and services result in reduced purchasing power of people. For employees, the second most important motivation factor was social benefits. Social benefits, like the above stated standard services provided to employees by the enterprise, can be an important saving money factor related with the job, providing e.g. transport, meals, retraining courses or offering different services, relaxation and recreation important for physical and psychological regeneration. The next motivation factors were job security followed by good working team, highlighting the need of togetherness and good workplace relations. The fifth most important motivation factor was further financial reward confirming the significance of finances at the time of economic recession.

Table 3 The most important motivation factors in the year 2012
Tablica 3. Najvažniji motivacijski čimbenici u 2012. godini

S.N.	**Motivation factor** / *Motivacijski čimbenik*	∅
1.	Basic salary / *osnovna plaća*	4.82
2.	Social benefits / *socijalne naknade*	4.67
3.	Job security / *sigurnost radnog mjesta*	4.65
4.	Good working team / *dobar radni tim*	4.57
5.	Further financial reward /*dodatna financijska nagrada*	4.55
6.	Work environment / *radno okruženje*	4.43
6.	Work performance / *izvedba poslova*	4.43
8.	Self - actualization / *samoaktualizacija*	4.42
9.	Supervisor' s approach / *supervizorski pristup*	4.38
10.	Fair appraisal system / *pošten sustav ocjenjivanja*	4.31

Even though by comparing the levels of motivation in the year 2004 and 2012, changes in mean values arise, significant change of motivation factors ($p<0.05$) arises only in connection with factors like working hours, moving up the corporate ladder, competences, prestige, social benefits, region development (Tab. 4). In spite of the expectations that, due to the economic crisis, the employees' demands would change and that they would be willing to work in worse working conditions, our assumptions did not prove true.

Based on the actual survey of employee motivation (Hitka, 2009a, 2009b), it can be stated that employees in manufacturing enterprises have generally kept the level of motivation during 5-6 years. Assumptions that, due to the world economic crisis and its economic and social impacts, the motivation level of employees in the woodworking industry would change significantly, did not prove true. Moreover, the order of motivation factors did not change fundamentally.

Table 4 Comparison of the significance of motivation change in the year 2004 and 2012
Tablica 4. Usporedba značenja motivacijskih čimbenika u godinama 2004. i 2012.

Motivation factor *Motivacijski čimbenik*	**Mean** *Srednja vrijednost*	**Mean** *Srednja vrijednost*	***t*-value** *t-vrijednost*	***p***
	2004	**2012**		
Atmosphere at workplace / *atmosfera na radnome mjestu*	4.55	4.33	1.82	0.071
Good working team / *dobar radni tim*	4.68	4.55	1.33	0.188
Further financial reward (13th, 14th salary) / *dodatna financijska nagrada*	4.55	4.57	-0.13	0.898
Physical effort at work / *fizički napori na poslu*	3.53	3.70	-0.95	0.345
Job security / *sigurnost radnog mjesta*	4.65	4.65	0.00	1.000
Communication at workplace / *komunikacija*	4.18	4.37	-1.21	0.228
Company name / *naziv tvrtke*	4.17	4.15	0.11	0.916
Opportunity to use own abilities / *mogućnost primjene vlastitih sposobnosti*	4.33	4.18	1.13	0.261
Workload and type of work done / *radno opterećenje i vrsta posla*	4.10	4.12	-0.12	0.906
Familiarisation with reached working results / *upoznavanje s postignutim rezultatima*	3.98	4.18	-1.25	0.212
Working hours / *radno vrijeme*	**3.82**	**4.17**	**-2.09**	**0.039**
Work environment / *radno okruženje*	4.25	4.43	-1.18	0.242
Work performance / *izvedba poslova*	4.12	4.35	-1.64	0.104
Moving up corporate ladder / *uspon na korporativnoj ljestvici*	**4.10**	**4.43**	**-2.27**	**0.025**
Competences / *kompetencije*	**4.12**	**3.75**	**2.31**	**0.023**
Prestige / *prestiž*	**4.32**	**3.80**	**3.23**	**0.002**
Supervisor's approach / *supervizorski pristup*	4.45	4.38	0.49	0.624
Individual decision making / *samostalno donošenje odluka*	4.25	4.13	0.96	0.339
Self-actualization / *samoaktualizacija*	4.17	3.97	1.38	0.170
Social benefits (utilisation of social fund) / *društvene koristi (korištenje socijalnog fonda)*	**4.00**	**4.42**	**-2.60**	**0.010**
Fair appraisal system / *pošten sustav ocjenjivanja*	4.57	4.67	-0.65	0.518
Stress / *stres*	4.48	4.38	0.70	0.488
Mental effort / *mentalni napor*	4.05	4.32	-1.57	0.119
Company vision / *vizija tvrtke*	4.12	4.27	-0.92	0.359
Region development / *razvoj regije*	**3.85**	**4.23**	**-2.25**	**0.026**
Education and personal growth / *obrazovni i osobni rast*	4.18	4.25	-0.49	0.627
Company relation to environment / *odnos tvrtke prema okolišu*	4.13	4.33	-1.36	0.176
Free time / *slobodno vrijeme*	3.97	4.18	-1.18	0.240
Recognition / *priznanje*	4.27	4.28	-0.11	0.913
Basic salary / *osnovna plaća*	4.68	4.82	-1.06	0.291

Significant changes are in bold / *značajne promjene su otisnute poludebelim slovima*

4 CONCLUSION
4. ZAKLJUČAK

As indicated in the introduction of this paper, the source of the entire activity, productivity and prosperity of enterprises lies in human resources. Therefore, enterprises should provide working conditions for their employees that can ensure a suitable level of employee motivation. It is a general truth that even the best employee must not only be able to work - to have suitable skills for the given work, but he must also want to work - which implies that the level of his motivation to work and his willingness to work is high. The basic conditions to improve work performance and achieve goals related to personnel performance, especially at the time of the economic crisis, is to know different methods and forms of motivation and their implementation in the working process.

The aim of this paper was to consider the effect of the world economic crisis and its economic and social impacts on the change in employee motivation in the selected woodworking enterprise. The analysis of motivation factors was carried out in the analysed enterprise by the method of inquiry in the year 2004 and 2012. The acquired data were evaluated through methods and tools of descriptive and testing statistics. The research results show that the order of importance of motivation factors, developed on the basis of the obtained mean value, changed and however significant change in perception of importance of individual motivation factors arose only in 20 % of factors, i.e. in 6 out of 30 factors. Significant change occurred in connection with factors like working hours, moving up the corporate ladder, competences, social benefits and region development (Tab. 4). The most important finding of the survey, resulting from statistical testing, is that the effect of the world economic crisis, and its economic and social impacts, does not lead to a significant change in the level of employee motivation in woodworking industry.

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Evaluation of Material Characteristics of Xylite – Part 2. Characterization of Drying Defects

Procjena obilježja ksilita - dio 2. Karakterizacija grešaka sušenja

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ABSTRACT • *Xylite very much has the appearance of precious wood species with dark heartwood and also has some physical and aesthetical properties of wood, required nowadays for making valuable products. Xylite, with well recognizable and preserved wood structure, was used for studying the drying kinetics and drying quality. The drying experiments were carried out at 20 °C and 40 °C using constant relative air humidity ranging from 34 % to 87 %, on elements 6 mm, 12 mm and 18 mm thick. The visual assessment of the drying quality was additionally made by light microscopy fracture analysis. The drying time increased with the increase of relative humidity and thickness of specimens. The yield of dry material decreased with the increase of drying time and with the increase of specimen thickness. End-splitting and bowing were the most common drying defects on tangentially oriented specimens. The failure usually occurred in collapsed earlywood, in disoriented tissue or in places with soil or mineral inclusions.*

Keywords: *xylite, drying, drying defects, drying time, microscopy*

SAŽETAK • *Ksilit izgledom podsjeća na dragocjene vrste drva tamne srži i još posjeduje relevantna fizikalna i estetska svojstva drva koja su poželjna za izradu vrijednih proizvoda. Na uzorcima ksilita dobro vidljive i očuvane strukture drva istraživana je kinetika sušenja i kvaliteta osušenih elemenata. Eksperimenti sušenja izvedeni su s elementima ksilita debljine 6, 12 i 18 mm, pri temperaturama 20 i 40 °C u intervalu relativne vlažnosti zraka od 34 do 87 %. Vizualna procjena kvalitete dodatno je ispitana primjenom frakturne analize i svjetlosnog mikroskopa. Vrijeme sušenja produžavalo se s povećanjem relativne vlažnosti zraka i debljine elemenata, a kvalitativno iskorištenje materijala smanjivalo se s produljenjem vremena sušenja i s povećanjem debljine elemenata. Glavne greške sušenja bile su čeone pukotine i uzdužno zakrivljenje tangencijalno orijentiranih uzoraka. Najčešće mjesto grešaka sušenja bilo je kolabirano rano drvo, na mjestima velike dezorijentacije vlakanaca te tkiva s mineralnim i zemljanim inkluzijama. Savijanje osušenih uzoraka ksilita dodatno se pripisuje povećanju gustoće tog materijala.*

Ključne riječi: *ksilit, sušenje, greške sušenja, vrijeme sušenja, mikroskopija*

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1 INTRODUCTION
1. UVOD

The Velenje lignite and xylite (as lithotype of lignite) seam is embedded approximately in the middle of the Plio-Pleistocene succession (Markič and Sachenhofer, 2010). During a long period of time, wood structure undergoes a drastic biochemical, geochemical and geological transformation, as well as carbonization (Drovenik, 1982; Justin and Markič, 2005). Anyway, it still retains some physical and mechanical behaviour of wood from which it originates (Gorišek *et al*., 2012; Gorišek and Straže, 2103). Still well preserved xylem structure may have a potential for use in some specific, often highly valuable end products. The research is a continuing attempt to convert low grade xylite into products of higher quality and more added value, as energy source, compared to primarily used briquetting and gasification (Anon., 2005; Gorišek, 2007).

When xylite does not contain great amounts of mineral inclusions, it can be processed with wood working machines. Especially when polished, it often shows recognizable structure of wood and its colour resembles to wood species with dark coloured heartwood, like wenge (*Milletialaurentii*) or ebony (*Dyospiros* sp.). The unpleasant fact is that xylite retains the worst characteristic of wood. Xylite remains hygroscopic; therefore, if it is to be used in normal climatic conditions, it should be dried to the appropriate moisture content that can ensure dimensional stability during use. Therefore, during the drying process, a large amount of bound water should be removed. Due to high density, the diffusion process in xylite is very slow, shrinkage is pretty high and a significant reduction of strength is expected. In this case, the drying needs to be considered as a low-stress loading of xylite, due to moisture content changes and drying gradient that cause high risk of warping and cracking in the process of drying or during exposure to changing climatic conditions.

The main aim of this research was to study the feasibility of conventional drying of xylite and the drying conditions affecting the kinetics of the procedure and the end product quality. Furthermore, typical drying defects were classified and the main causes were evaluated at the microscopic level of xylite structure.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

For the study, individual pieces of xylite were selected from the regular production line of lignite mine. Strong heterogeneity and large variability of xylite required visual assessment of material to select the pieces with the best preserved and recognizable wood structures.

For drying, specimens of three thicknesses (6 mm, 12 mm and 18 mm) were cut and sorted according to the material density and colour assessment.

The drying process was carried out in thermostatically controlled chambers at two temperature levels (T_1 = 20 °C and T_2 = 40 °C). The different drying potentials were achieved by constant climatic conditions with four saturated salt solutions (RH_1 = 34 % ($MgCl_2$), RH_2 = 65 % ($NaNO_2$), RH_3 = 75 % (NaCl) and RH_4 = 86 % ($ZnSO_4$)), while for the drying at the highest temperature (T_2), just two climatic conditions were used (RH_2 = 61 % ($NaNO_2$), RH_4 = 84 % ($ZnSO_4$)). The average air velocity at the entry of the stack of 1.0 m/s was achieved by radial fans.

The final quality control of dried xylite included the evaluation and macroscopic characterization of internal and external xylite cracking and possible geometrical changes like warping and anisotropic shrinkage. Microscopic characterization, including fracture and anatomy analysis, followed afterwards, and it was carried out using standard transmittance light microscopy techniques and differential colour staining. The yield of volume without damages was used for assessing the quality of dried xylite.

In order to determinate and describe the defects, the criteria were established for evaluating the defect on transverse and longitudinal sections. The transverse sections were evaluated by:

- presence of inclusions (minerals, soil);
- type and direction of cracks (orientation: radial, tangential, other) and their occurrence (earlywood, latewood, in the middle lamella or in the cell walls);
- assessment and extent of cracks (length - width);
- consistence of earlywood (appearance of tissue, presence of cracks and inclusions; degree of collapsed tissue);
- width of early and late wood and its proportion;
- number of cells in a radial series;
- shape and appearance of cells (e.g. cell wall thickness, number of layers in the cell wall, presence of radial cracks in the cell wall, depth of radial cracks in the cell walls) and
- degree of collapsing.

The longitudinal sections were additionally estimated by:

- occurrences of helical indentations and cracks;
- presence of slip panes and fractures, also other types of cracks;
- size and quantity of parenchyma tissue and
- presence of other inclusions.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The drying of xylite started from the average initial moisture content of 43.3 % to the final moisture content (MC_f) achieved with equilibrium moisture content upon exposure to individual climatic conditions. The lowest MC_f was reached at T = 20 °C and 34 % RH, namely 8.0 %, whereas the highest MC_f of 25.0 % was attained in the most humid climatic conditions (RH_4 = 87 %) (Gorišek *et al*., 2013).

The drying time depended on the drying conditions, as well as on thickness of individual specimens (Tab. 1).

Table 1 Drying time of xylite at different drying regimes
Tablica 1. Vrijeme sušenja ksilita pri različitim uvjetima

Drying time, h *Vrijeme sušenja, h*	**Drying temperature** / *Temperatura sušenja* T_1 = 20 °C				**Drying temperature** *Temperatura sušenja* T_2 = 40 °C	
Thickness *Debljina*	φ = 34 %	φ = 65 %	φ = 75%	φ = 86 %	φ = 61%	φ = 84 %
d = 6 mm	190.2	381.6	502.0	857.6	72.0	194.4
d = 12 mm	285.4	453.3	526.8	888.1	105.1	262.5
d = 18 mm	474.2	507.3	583.8	936.4	207.3	376.1

The dependency of the drying process time and specimen thickness is well correlated and can be successfully fitted to the exponential regression model. Generally, drying at the normal climatic conditions (20 °C / 65 %) or drier climate resulted in a sufficiently short drying time, whereas lower drying potential was less successful. Comparison between the procedure duration and some known drying kinetics models (Simpson and Tschernitz, 1980, Bekhta *et al*., 2006, Trübswetter, 2006) confirmed a very low diffusion coefficient for the transport of bound water.

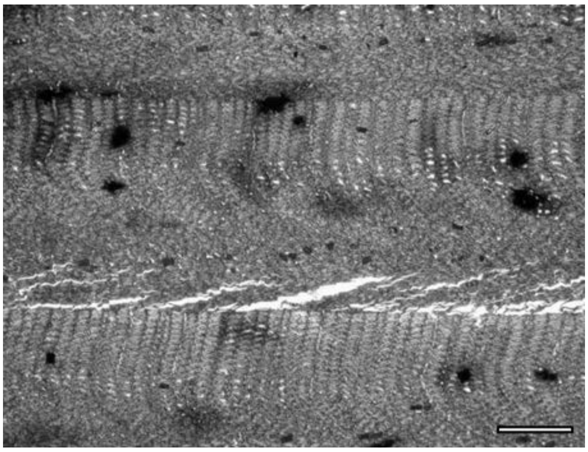
The results of final quality control of drying showed a low yield of xylite suitable for use for final products. Higher quality was obtained by drying in mild conditions and at lower temperature (Tab. 2), whereas it decreased with the increase of thickness of xylite specimens. This can be ascribed to assumed increase of drying stresses with thicker material, often found during drying of natural sawn wood (Hunter, 2002; Pang, 2002; Thuvander *et al*., 2002; Kang *et al*., 2004), and also due to a probably higher content of mineral and other inclusions in thicker specimens, not detected during visual inspection. Greater heterogeneity and disorientation of the investigated xylite structure could also cause more fractures in thicker xylite elements. Compared to the drying time at different time regimes, the yield of quality dried xylite is negatively correlated to the duration of the procedure (Tab. 1).

Table 2 The average yield of xylite specimens suitable for end use after drying at different regimes
Tablica 2. Prosječan postotak iskoristivog ksilita nakon sušenja pri različitim uvjetima

Yield, % *Iskorištenje*, %	**Drying temperature** / *Temperatura sušenja* T_1 = 20 °C				**Drying temperature** *Temperatura sušenja* T_2 = 40 °C	
Thickness *Debljina*	φ = 34 %	φ = 65 %	φ = 75%	φ = 86 %	φ = 61%	φ = 84 %
d = 6 mm	55.5	70.0	61.0	67.0	60.1	61.5
d = 12 mm	43.1	65.0	51.0	60.0	60.7	64.3
d = 18 mm	45.5	54.9	58.8	54.6	43.3	51.1

The most common defects that reduce the quality and ability of exploitation of xylite were reflected in various types of cracks and different kind of warping.

End splitting and cleavage occurred more frequently in xylite than in some wood species (Chen *et al*., 1997; Oltean *et al*., 2007; Ratnasingam *et al*., 2010). Cracking of xylite mostly occurred in tangential direction. This is opposite to the usual checks of wood, where large tangential shrinkage induces radially oriented cracks typically at the junction of rays and longitudinally oriented fiber-form tissue (Oltean *et al*., 2007; Ratnasingam *et al*., 2010). In xylite, the transverse shrinkage anisotropy is not so marked and reaches the value of around 1.5 (Gorišek *et al*., 2012), which is considerable less than in most wood species (Dinwoodie, 2000).). Therefore, the large difference in shrinkage is not between the radial and tangential direction but between more or less different structures of parallel layers (Fig. 1). Typical tangentially oriented cracks emerged on the border between often collapsed earlywood cells and better preserved latewood cells. In these locations, early-wood was often laying over latewood (Fig. 2). Delamination between earlywood and latewood in tangential plan can be ascribed to different shrinkage and different rigidity of cell walls in these two categories.



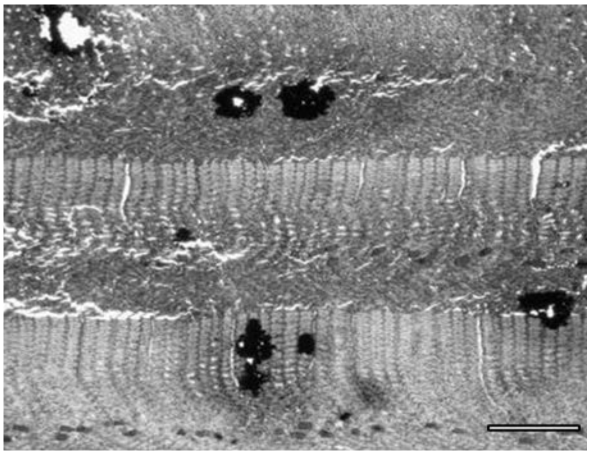
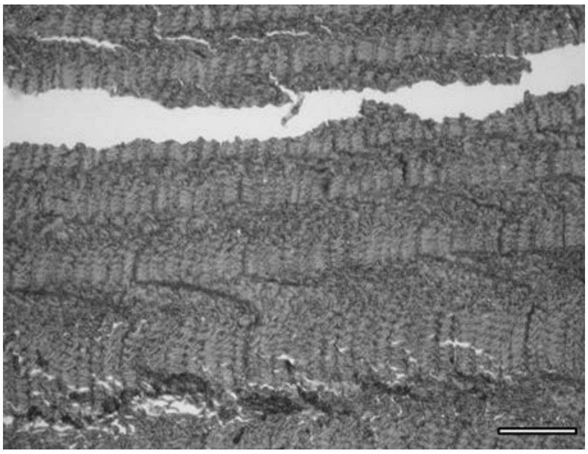


Figure 1 Cross-sections of xylite: Failures are most common in places with large differences in density and sharp transition from earlywood to latewood and in slip layers of earlywood (the shear strength of collapsed cell walls is weakened). Bars – 100 μm
Slika 1. Poprečni presjeci ksilita: pukotine se najčešće nalaze na mjestima velikih razlika gustoće i oštrog prijelaza iz ranog u kasno drvo te u posmaknutim slojevima ranog drva (čvrstoća smicanja urušenih staničnih stijenki smanjena je). Trake - 100 μm



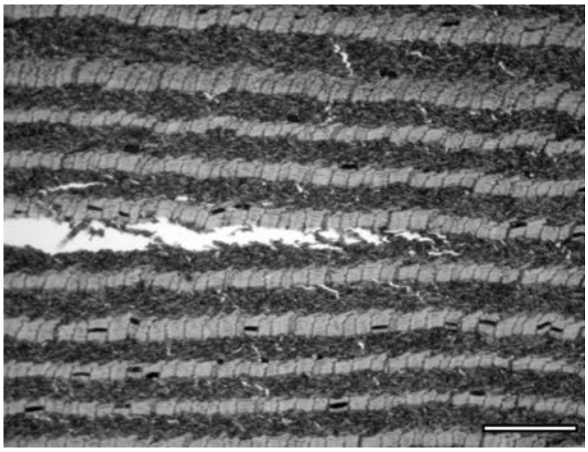


Figure 2 Cross-sections of xylite: Splitting caused by heavily disoriented tissue in intercalating and kneading fibers also weakened by soil and mineral inclusions. Bars – 100 μm
Slika 2. Poprečni presjeci ksilita: razdvajanje tkiva uzrokovano je vrlo dezorijentiranim staničjem u zgnječenim i umetnutim vlaknima koja su oslabljena inkluzijama minerala i zemlje. Trake - 100 μm

Failures are most common in places with large differences in density and sharp transition from earlywood to latewood as well as in slip layers of earlywood. Collapsed earlywood cell walls and slip layers in earlywood had very low shear strength (Fig. 3 and Fig. 4). Mineral and soil inclusion mainly arranged in tangential directions are probably the next weakening factor of xylite tissue in this direction and a possible place for initiating the fracture (Fig. 5).

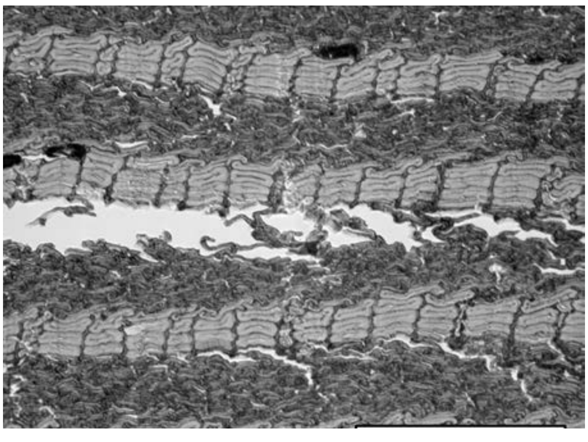


Figure 3 Cross-sections of xylite: End cracking is the result of large radial shrinkage, due to higher collapsing and densification of tissue in this direction. Bars – 100 μm
Slika 3. Poprečni presjeci ksilita: čeone su pukotine rezultat velikoga radijalnog utezanja zbog većeg urušavanja i povećanja gustoće tkiva u tom smjeru. Trake - 100 μm.

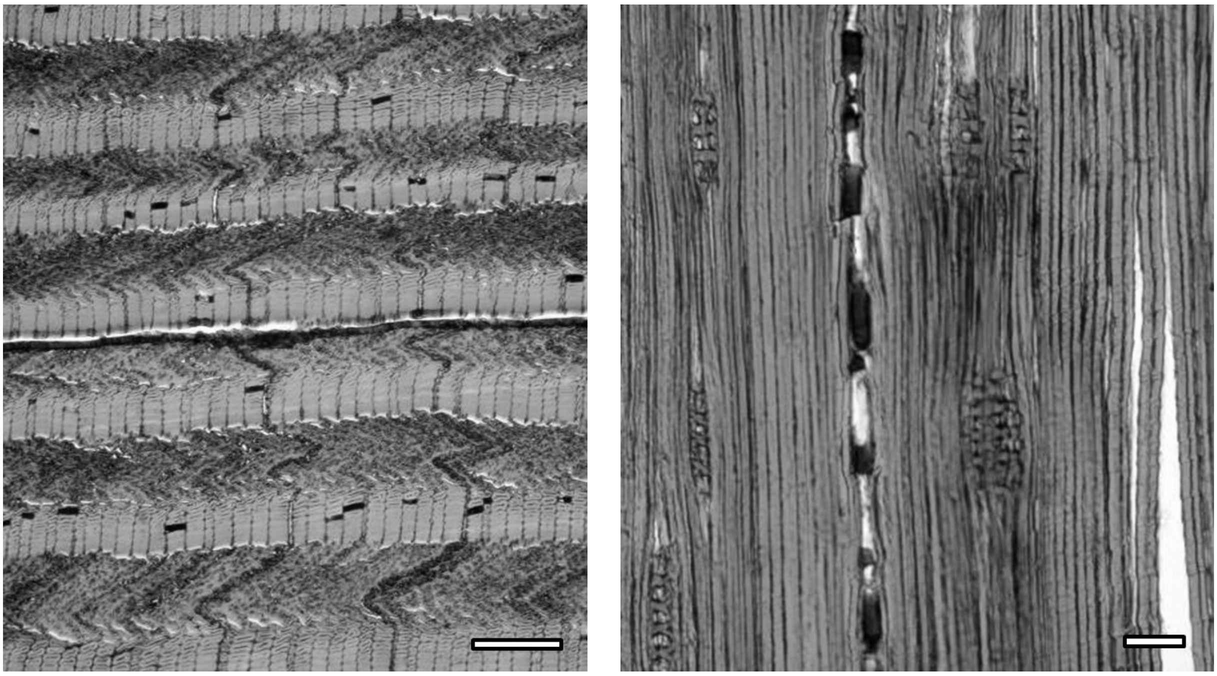


Figure 4 Cross-section (left) and tangential section (right) of xylite: Mineral and soil inclusions mainly arranged in tangential arches weaken the cohesion bonds between fibers. Bars – 100 μm
Slika 4. Poprečni presjek (lijevo) i tangencijalni presjek (desno) ksilita: inkluzije zemlje i minerala raspoređene u tangencijalnim lukovima oslabljuju kohezijske veze između vlakanaca. Trake - 100 μm.

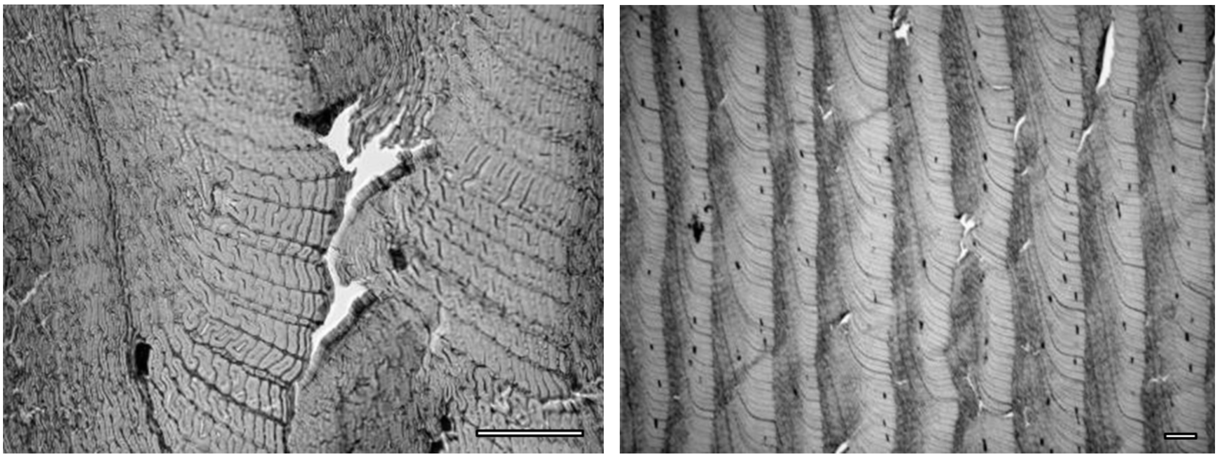


Figure 5 Cross-sections of xylite: Failure of cell walls and formation of slip planes are characteristic for earlywood. Bars – 100 μm
Slika 5. Poprečni presjeci ksilita: greške staničnih stijenki i stvaranje ravnina smicanja karakteristični su za rano drvo. Trake - 100 μm.

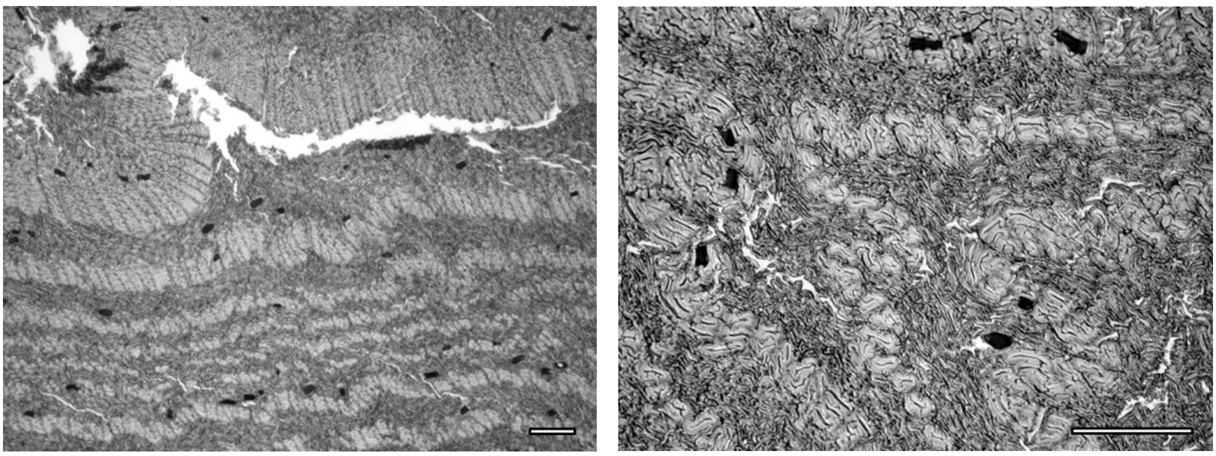


Figure 6 Cross-sections of xylite: Thinner pieces of xylite are subject to bowing and warping due to different orientation of layered structure and different overlying tissues. Bars – 100 μm
Slika 6. Poprečni presjeci ksilita: tanji komadi ksilita podvrgnuti su koritanju i krivljenju zbog različite orijentacije uslojene strukture te različitih staničja u preklapajućim slojevima. Trake - 100 μm.

Since the average shrinkage of xylite along the grain is significantly larger than in nowadays wood species (Gorišek *et al*., 2012), the occurrence of warp in xylite is also more frequent than in wood. Xylite was less susceptible to side bending (crook) than to warping along the length of the element face (bow) (Fig. 6), and more susceptible to bowing in thinner elements.

The main factor influencing the degree of crooking or bowing in a sawn wood is usually the original location in the log (juvenile wood) or the presence of reaction wood (Gorišek and Straže, 2004; Straže *et al*. 2011). It is quite difficult to identify the reaction or even juvenile tissues in xylite. As it is certain that the influence of long-term geochemical conversion from wood into xylite was significantly greater than the differences between various categories of wood, xylite warping is considered to be caused by densification processes, damages and reorientation of tissue. The largest differences are observed between less altered latewood with more rigid cell walls and collapsed thin cell walls of earlywood. Warp also appeared in locations with heavily reoriented tissue caused by intruding and kneading of fibers. In many bow-deformed elements, overlaid tissues were recognized with characteristic interwoven microstructure.

4 CONCLUSIONS
4. ZAKLJUČAK

The drying kinetics of xylite is similar and even slower than the drying kinetics of very dense wood species with high internal resistance to moisture flow. Nevertheless, the use of low drying potential, i.e. high relative air humidity and low temperature, increases the yield of quality dried xylite suitable for some specific products after drying.

Collapsed structure of xylite and its considerably reduced strength and dimensional stability were the main risks and defects during the drying process. Heterogeneity and presence of mineral and soil inclusions also have an important role in the xylite structure, especially with thicker elements.

Investigation of drying defects on microscopic level showed that the cracks are more frequently oriented in tangential direction. Failures are most common in completely collapsed earlywood or between earlywood and latewood. From there, associated with the presence of huge tissue disorientation, the initiated fractures usually cause serious surface checking and most often characteristic end-splitting of dried elements. Warping of dried xylite specimens, more present with thinner elements, can be ascribed to high densification and to local reorientations of xylite structure, while the influence of juvenility or reaction tissues have to be excluded.

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Influence of the Sawing Method on Yield of Beech Logs with Red Heartwood

Utjecaj načina piljenja na iskorištenje bukovih trupaca s lažnom srži

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ABSTRACT • *The paper presents the research of differences in quantitative and value yields, and structure of sawn timber and residues, whose appearance is caused by different methods of sawing beech logs with red heartwood. In order to achieve the goal, 45 logs were divided into three even groups and sawn into commercial timber using three methods: round, cant and live sawing. Similar quantitative yields were found for round sawing and cant sawing (60.63 % and 60.52 %, respectively), while a lower result of 56.79 % was observed for live sawing. Less timber (edged and red heartwood boards) and smaller products were found in live sawing than in other two methods, meaning that live sawing resulted in a lower value yield.*

Keywords: *beech, sawmill processing, methods of sawing, yield, red heartwood*

SAŽETAK • *Prilikom prerade bukovih pilanskih trupaca s lažnom srži na primarnim pilanskim strojevima primjenjuju se različiti načini piljenja. Najčešće su to kružno piljenje, prizmiranje i piljenje ucijelo. Cilj istraživanja bio je da se u preradi bukove oblovine, pri izdvajanju lažne srži u zasebne sortimente (srčanice), utvrdi utjecaj načina primarnog piljenja na kvantitativno i vrijednosno iskorištenje, kao i na sortimentnu strukturu dobivenih proizvoda. Za istraživanje su odabrani bukovi pilanski trupci promjera 40 - 49 cm, duljine 4 m. Od uzorka koji je obuhvaćao 45 trupaca za primjenu navedenih načina piljenja formirane su tri ujednačene skupine od 15 trupaca. Istraživanje je izvedeno u industrijskim uvjetima. Trupci su primarno obrađeni tračnim pilama (trupčarom i paralicom) te je proizvedena piljena građa nominalne debljine 25 i 50 mm. Sekundarna obrada provedena je poprečno-podužno-poprečnim postupkom, na strojevima za individualno piljenje, a sitni su sortimenti izrađivani na stolarskoj tračnoj pili i kratilici za popruge. Kvantitativno iskorištenje pri kružnom piljenju iznosilo je 60,63 %, kod prizmiranja 60,52 %, a pri piljenju ucijelo 56,79 %. Nadmjera je bila približno 10 %. U sva tri načina piljenja udio krupnoga pilanskog ostatka bio je približno jednak udjelu piljevine. Kružnim je piljenjem dobivena najbolja kvaliteta sortimenata, ali i najveći udio srčanica. Prizmiranjem je dobiveno najviše piljene građe (ukupno - okrajčene i neokrajčene), kao i najveća količina najvrjednijih sortimenata – duge okrajčene piljene građe. Piljenjem ucijelo nastalo je znatno više sitnih sortimenata (četvrtača i popruga) nego pri drugim načinima piljenja, ali i najmanje srčanica. U sva tri načina piljenja prevladavale su piljenice tangencijalne teksture, zatim one poluradijalne teksture, dok je radijalnih bilo najmanje i većinom su to bile srčanice. Kružnim piljenjem i prizmiranjem postignuto je približno jednako vrijednosno iskorištenje, dok je piljenje ucijelo dalo nešto lošije iskorištenje.*

Ključne reči: *bukva, pilanska prerada, načini piljenja, iskorištenje, lažna srž*

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1 INTRODUCTION
1. UVOD

Beech is one of the most important wood species in Europe. One of its characteristics is red heartwood, which develops in the center of the tree and differs from outer wood (sapwood) by its red color. Knoke (2003) reported that the appearance and size of red heartwood was influenced by diameter, height and age of a tree, its branchiness, share of crown in total height of a tree and the width of growth rings, but that the greatest influence came from tree dimensions and age. Wernsdörfer *et al*. (2005) researched the relation between shape and size of red heartwood and stem external features (dead branches, branch scars, wounds, cracks, forks) and stated that the influence of scars was notable in some cases and that it was related to the size of the defect and the rate of entrance of oxygen into the tree.

The yield of beech round wood is related to the presence of red heartwood (Škaljić, 2002; Popadić and Todorović, 2009). In general, the yield of raw material, as well as the quality and dimensional structure of sawn products, depends on the method of sawing (Zubčević, 1973; Gregić, 1982; Skakić, 1985; Hapla and Ohnesorge, 2005), the quality of raw material (Petutschnigg and Katz, 2005; Šoškić and Milić, 2005; Šoškić and Popadić, 2007), the dimensions of the log (Zubčević, 1973; Tanušev *et al*., 2009), the board marker accuracy (Buehlmann and Thomas, 2002, 2007), the technology applied (Zubčević, 1973) and the choice between single-phase and two-phase technological process (Zubčević, 1973; Gregić, 1982; Skakić, 1985).

In recent years, there has been a certain demand for timber made from red heartwood. Designers use it to create unique products and, however, its presence is usually not tolerated in commercial interior products (Prekrat *et al*., 2004). Therefore, in sawmill processing, it is necessary to separate sapwood from red heartwood. The shape of red heartwood in a log is difficult to predict, which complicates the planning of sawmill processing. Log-scanning technologies are not used for beech logs, and one of the reasons for this lies in similar densities of sapwood and red heartwood (Škaljić, 2002; Popadić and Todorović, 2008). Therefore, the processing of beech logs is usually carried out on log band saws.

Separation of sapwood and red heartwood can be done on both primary and secondary machines. In the first case, round sawing or cant sawing is applied, whereas in the second case, live sawing is applied on the primary machine, and the separation is done on rip saw machines. It needs to be said that, in some cases, the presence of red heartwood can be tolerated in sawn timber on a lower-quality side, while in others it is not tolerated at all.

The goal of this research is to determine the influence of the method of primary sawing on the yield and product structure of beech wood.

2 MATERIAL AND METHOD
2. MATERIJAL I METODA

Beech sawlogs, 40–49 cm in diameter and 4 m long, were used in this research. Such logs provide sufficient red heartwood (Nikolić. 1971; Knoke, 2003) and are, therefore, suitable for comparing the influence of different sawing methods on yield. A total of 45 logs without rot were selected from 42 trees felled in the area of Majdanpek, Serbia. Red heartwood was be round and healthy. Three groups made of 15 logs were prepared for different methods of sawing. These groups were the same regarding the log quality (number and sizes of knots, sweep, shape of cross section, spiral grain, diameter of red heartwood) and dimensions. Average dimensions of the processed logs are shown in Table 1.

Table 1 Average dimensions of processed logs
Tablica 1. Prosječne vrijednosti dimenzija prerađenih trupaca

Parameter / *Parametar*	**Method of sawing** / *Način piljenja*		
	Round / *Kružno*	Cant / *Prizmiranje*	Live / *U cijelo*
Thin end log diameter / *promjer na tanjem kraju trupca, cm*	44.40 (3.146)	43.97 (2.266)	43.53 (2.649)
Red heartwood diameter on thin end of log / *promjer lažne srži na tanjem kraju trupca, cm*	20.73 (3.727)	19.67 (3.913)	19.32 (4.46)
Mid length diameter / *promjer na sredini trupca, cm*	45.60 (2.971)	44.73 (2.463)	45.00 (2.803)
Thick end diameter / *promjer na debljem kraju trupca, cm*	50.27 (3.788)	48.08 (3.131)	48.83 (4.308)
Red heartwood diameter on thick end of log / *promjer neprave srži na debljem kraju trupca, cm*	20.80 (5.609)	21.20 (3.697)	20.78 (4.100)
Length of log / *duljina trupca, m*	4.203 (0.174)	4.145 (0.099)	4.157 (0.098)
Log volume / *volumen trupca, m³*	0.731 (0.112)	0.682 (0.073)	0.690 (0.089)

Note: values of standard deviation are in parentheses / *Napomena: vrijednosti standardne devijacije navedene su u zagradama.*

The measurements (precision of 5 mm) taken were: length of log (*l*), diameters without bark (thin end - *d*, mid length – d_m, thick end - *D*), diameters of red heartwood. Thickness of bark was measured with precision of 0.2 mm, and mean value of four sample measurements on each log was used. Values of diameters were calculated as the mean value of two cross-measurements. All dimensions were rounded to the nearest centimeter, except for the thickness of bark.

Volume of logs without bark (V_l) was calculated according to the formula:

$$V_l = \frac{\left(\frac{d + d_m + D}{3}\right)^2 \pi}{4} \cdot l \tag{1}$$

Volume of bark was calculated as the difference between volumes of each log with and without bark.

Primary sawing was carried out on a log band saw (Bratstvo, flywheels diameter 1100 mm) and a band resaw (Canali, flywheels diameter 1100 mm). Logs were sawn into 25 and 50 mm thick timber, parallel to the central log axis, with thin end forward. Blade parameters were: width - 130 mm (band saw) and 90 mm (band resaw), thickness – 1.20 mm (band saw) and 1.0 mm (band resaw) and breadth of swage set on one side: – 0.3 mm (for both blades). Secondary sawing was carried out by the cut-first process on machines with individual cuts, and smaller products were made on a band saw and a cross cut saw. With the exception of sawdust, all wood waste was collected and the mass was measured (precision of 0.5 kg).

Round sawing, cant sawing and live sawing were used as the sawing patterns (Figure 1).

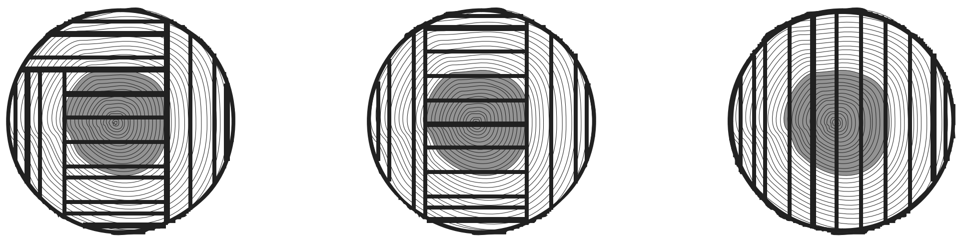

Figure 1 Sawing patterns for beech logs with red heartwood (a – round sawing, b – cant sawing, c – live sawing)
Slika 1. Osnove piljenja za bukove trupce s lažnim srcem (a – kružno piljenje, b – prizmiranje, c – piljenje ucijelo)

Sawing patterns were not predefined but they were adapted according to quality, dimensions and shapes of logs. Separation of red heartwood by round sawing and cant sawing was carried out with a log band saw, and by live sawing separation was carried out on secondary machines.

The main goal of processing was to make products of the highest quality and highest possible value. Un-edged and half edged boards, long and short edged boards, red heart boards, as well as small products (elements for flooring strips, squares, etc.) were produced. The standard applied in this process was SRPS D. C1.022, which is similar to European EN 975-1 standard. The thicknesses of the boards were: 27 mm (nominal 25 mm) and 54 mm (nominal 50 mm). Dimensions of products were measured with the precision of 1 mm, then they were calculated to standard values and the difference in volume was used to determine the actual oversize. Quantitative yield was calculated by dividing the volume of products by the volume of log without bark. Analysis of the timber structure was done for each group of products (unedged timber, edged timber, small products, etc.), calculated as the share in the total volume of timber.

Due to its irregular shape, total volume of large wood waste (slabs, edgings and trimmings) was calculated as a ratio of waste wood mass and wood density. The average wood density was calculated based on five randomly chosen products from each log, by measuring their mass and dimensions. The volume of sawdust was obtained as a difference between the log volume and sum of product volume and large wood waste volume.

Quantitative yield is a very important indicator of sawmill processing successfulness, but the objective assessment of the effects of production is often made by the value yield. This is often calculated by using the value of production, expressed in a currency per unit of the area or volume (Steele *et al*., 1993; Popović *et al*., 2003; Shepley *et al*., 2004). Such method is simple and practical and it was used as one of the indicators of value yield in this research. Unlike this, Zubčević (1973), Skakić (1985) and Tanušev *et al*. (2009) calculated the value yield as the product of quantitative and qualitative yield. Value yield calculated in such a manner represents only the value of products but omits some factors, such as entry-value of raw material, which is influenced by numerous factors (Knoke *et al*., 2006), and the amount of work and energy used in processing. Hapla and Ohnesorge (2005) reported that cutting costs are somewhat below the value of logs. These factors can be included in the calculation of value yield and in this research this was done according to the formula (Šoškić and Popadić, 2010):

$$c_{vi} = \frac{c_{qy} \cdot c_p \cdot c_{vt}}{c_{vl}} \cdot c_{cp} \quad (2)$$

where:

c_{vi} – coefficient of value increase – measure of value yield;

c_{qy} – coefficient of quantitative yield;

c_p – price coefficient – quotient of average prices of timber and logs;

c_{vt} – mean coefficient of value of timber – measure of real value of timber, compared to a theoretic maximal value;

c_{vl} – coefficient of value of logs – measure of value of logs, compared to an average value;

c_{cp} – coefficient of complexity of processing – indirect indicator of the amount of work, determined by the ratio between the average product volume of each log and the average product volume of all logs.

One-way ANOVA and LSD post hoc analysis (SPSS 13.0 software) were used for comparing and determining any significant differences between data groups.

3 RESULTS AND ANALYSIS
3. REZULTATI I ANALIZA

Structure of sawmill products made of beech wood is shown in Table 2.

The data show that round sawing and cant sawing (tangential methods of sawing) had a higher quantitative yield compared to live sawing. Live sawing yield was lower by 3.84 % compared to round sawing, and 3.73 % compared to cant sawing. This is in good agreement with Steele (1984), who reported that the yield of tangential methods of sawing was, on average, higher by 3 % compared to live sawing. However, in this research differences were not statistically confirmed (F=3.077; p=0.057) due to high variation within the groups. In general, the quantitative yield was higher than that reported in other papers (Zubčević, 1973; Skakić, 1985; Šoškić and Milić, 2005). The cause for this was that the logs with irregular shape and presence of rot were not used in this research.

Structures of waste were similar regardless of the method of sawing. High variation between logs was found (coefficient of variation of sawdust was up to 20 %, and that of large waste was between 20 % and 30 %). The cause of this phenomenon may be a very heterogeneous structure of timber products, which results in different secondary processing. Similar share of sawdust was recorded by Šoškić (1990), who reported the amount of 17 %, Popović *et al*. (2003) 19.7 % and Skakić (1985) reported 9–10 % of sawdust in the first processing phase and another 3–5 % in the second.

The amount of unedged timber was lower in cant sawing than in live and round sawing. However, because of high variations within the groups, the difference was not significant (F=0.415; p=0.663). The share of these products mostly depends on the quality of raw material (Popadić and Todorović, 2009), which was equalized in this research. The share of edged timber

Table 2 Structure of yield (%) depending on the method of sawing
Tablica 2. Struktura iskorištenja (%) u ovisnosti o načinu piljenja

Products / *Proizvodi*	**Method of sawing** / *Način piljenja*		
	Round / *Kružno*	Cant *Prizmiranje*	Live / *Ucijelo*
Un-edged timber / *neokrajčena građa*	8.69	15.26	19.18
Half edged timber / *poluokrajčena građa*	10.47	1.57	0.00
Total, un-edged and half-edged timber / *ukupno, neokrajčena i poluokrajčena građa*	19.16 (8.28)	16.83 (8.62)	19.18 (7.46)
Edged timber / *okrajčena građa*, $L \geq 2$ m	3.09	5.90	0.18
Edged timber / *okrajčena građa*, $L < 2$ m	9.02	13.69	7.59
Total, edged timber / *ukupno, okrajčena građa*	12.11 (3.14)	19.59 (3.98)	7.77 (5.71)
Red heart timber / *srčanice*	19.67 (6.30)	13.97 (4.14)	11.85 (4.58)
Small products (elements for flooring strips, squares, etc.) *sitni proizvodi (popruge, četvrtače itd.)*	9.69 (3.29)	10.13 (3.13)	17.99 (3.76)
Raw material yield / *kvantitativno iskorištenje sirovine*	60.63 (3.32)	60.52 (5.56)	56.79 (5.29)
Large waste / *krupni ostatak*	13.77	15.50	16.31
Sawdust / *piljevina*	15.79	14.70	16.70
Total, Waste / *ukupno, ostatak*	29.56 (3.16)	30.20 (6.48)	33.01 (5.11)
Oversize / *nadmjera*	9.81 (0.89)	9.28 (1.20)	10.20 (1.04)
Total / *ukupno*	100.00	100.00	100.00

Note: values of standard deviation are in parentheses / *Napomena: vrijednosti standardne devijacije navedene su u zagradama.*

differed in all three methods of sawing (F=27.521; p=0.000). Cant sawing yielded most edged timber because using this method long edged timber was produced from log sides that contained wood of the highest quality. With the other two methods of sawing, unedged and halfedged timber was produced from these parts. Round sawing produced a lower amount of long edged timber than cant sawing, and live sawing produced almost no such product. Cant sawing also yielded more timber in total compared to the other two methods (F=4.526; p=0.017).

Round sawing produced the highest number of red heart boards compared to other methods (F=9.445; p=0.000). According to the applied standard, the minimum width of half edged timber is greater than that of edged timber (4 cm difference). Consequently, in round sawing, turning of logs was often done before the red heartwood was reached, whereas in cant sawing the height of a cant was most often dictated by the diameter of red heartwood. Therefore the width of red heart boards produced by round sawing was wider than of those produced by cant sawing. Fewest red heart boards were recorded by live sawing because they were produced on secondary machines, where a more precise process is applied. A lower share of red heart boards in live sawing than in cant sawing is in a good agreement with the results obtained by Kenjić (according to Škaljić, 2002) who researched the influence of diameter of beech logs, diameter of red heartwood, and method of sawing on quantitative yield. He reported that the share of red heart boards was higher than 20 %, while other authors (Zubčević, 1973; Skakić, 1985; Šoškić and Milić, 2005) recorded much lower values – around 10 %. This difference, along with the above causes, depends on the level of tolerance toward the presence of red heartwood in final products, as well as on the ratio of red heartwood in the log diameter. The quantity of red heart boards is also influenced by their dimensions. Larger boards often contain an area of sapwood, which can be avoided in smaller ones.

Methods of sawing have a significant influence on the quantity of small products (F=28.188; p=0.000). Live sawing yielded larger quantities than tangential methods did. In all three methods, the elements for flooring strips were the dominant small products, while squares were produced in a higher amount only by live sawing. In this method, squares were produced from radial boards that, after separation of red heart, had no sufficient width.

Quantitative yield can also be observed, in a relative manner, as the presence of a product volume in the total volume of the product (Figure 2). In such a view, waste and oversize are not represented.

Regarding the product structure, live sawing clearly differed from tangential methods, especially in the quantity of small products. Considerable amount of

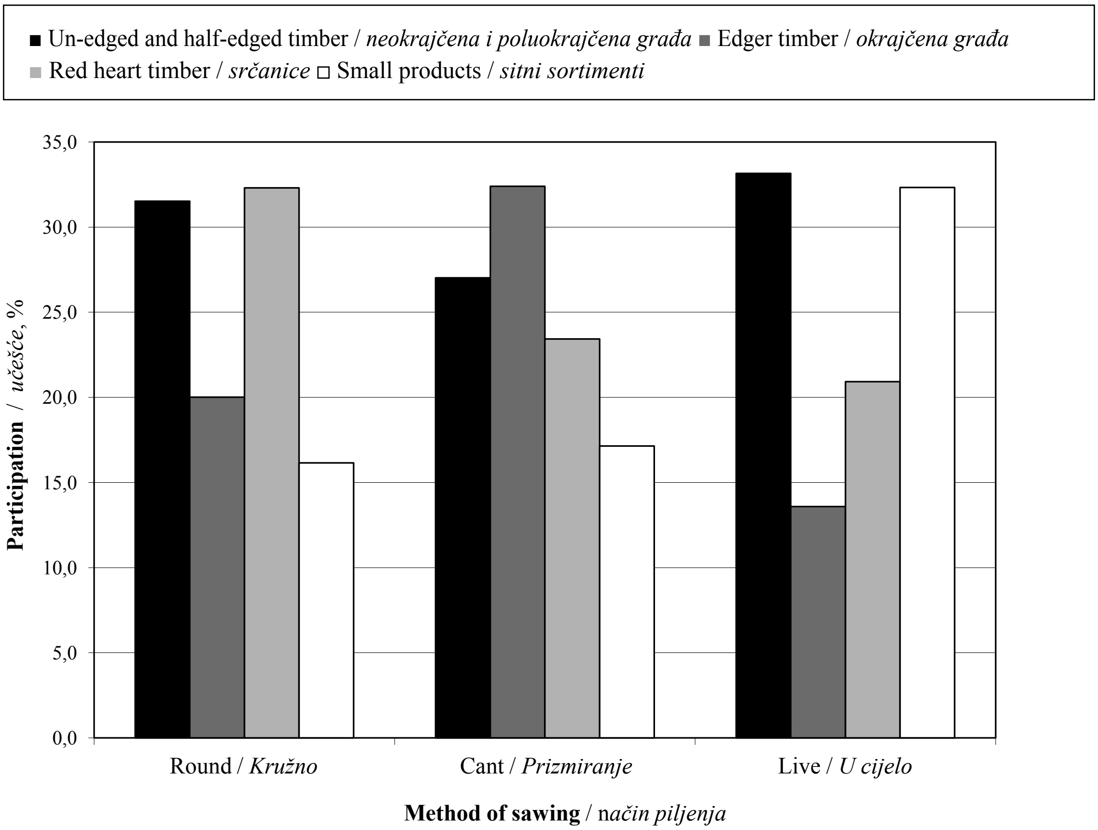

Figure 2 Relative yield of products for different methods of beech logs sawing
Slika 2. Struktura piljene građe u relativnom smislu pri različitim načinima piljenja

small products in live sawing caused the smallest average product compared to the average product of other two methods. The average product volume was: in round sawing – 3.129 cm^3, in cant sawing – 2.834 cm^3 and in live sawing – 1.769 cm^3, which implies that live sawing produced less valuable products, with more work invested.

The share of quarter-, rift- and flat-sawn boards in a log was interesting for analysis because flat-sawn products are most prone to developing deformations during drying. Beech timber made exclusively from sapwood, as the most valuable, is shown in Figure 3.

Regarding the volume of logs, all three methods produced more flat-sawn boards than others. Timber

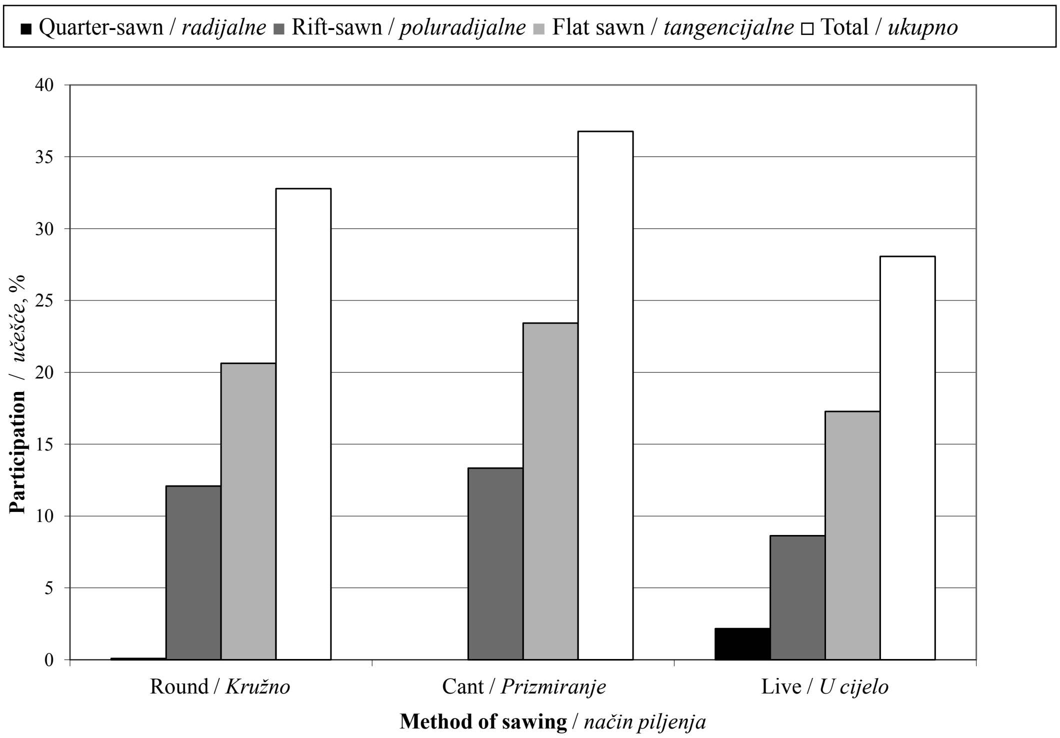

Figure 3 Structure of timber (from sapwood) according to growth ring orientation for different methods of beech logs sawing
Slika 3. Struktura piljene građe (od bjeljike) prema položaju godova prirasta pri različitim načinima piljenja bukovih trupaca

structure according to growth ring orientation was similar in round sawing and cant sawing. As expected, flat-sawn products were dominant in both tangential methods, as a result of the sawing method and position of quality zones in beech wood, while there were no quarter-sawn boards because from this zone only red heart boards were produced.

Quarter-sawn boards were obtained by live sawing, although in lower quantities than expected. It turned out that parts of quarter-sawn boards left after the separation of red heartwood did not have enough width to be used as timber, so they had to be processed into small products. Rift-sawn boards were produced from the inner, low-quality parts of logs, which, after removing the defects, also yielded small sawmill products. Therefore, the share of rift-sawn boards totaled one-third of timber in all sawing methods.

Quality was determined for large sawmill products: unedged, edged and red heart timber (Figure 4).

Timber of quality class I was dominant in all three methods of sawing with the highest value in round sawing. The share of class III was significantly lower, although the red heart boards were classified as class III. The share of red heart timber in class III was more than 90 % in round and live sawing and around 75 % in cant sawing. Products of class II were least represented in all the methods of sawing.

The effects of different methods of primary log-processing on quantitative and quality yield could be represented by value yield. It is shown in Table 3,

Table 3 Value yield of beech wood depending on method of sawing
Tablica 3. Vrijednosno iskorištenje bukovine u ovisnosti o načinu piljenja

Indicator / *Pokazatelj*	**Method of sawing** / *Način piljenja*		
	Round / *Kružno*	Cant / *Prizmiranje*	Live / *Ucijelo*
Value of products (€/m^3 of logs) *vrijednost proizvoda (€/m^3 trupaca)*	100.60	107.29	94.11
Coefficient of value increase (c_{vi}) *koeficijent uvećanja vrijednosti*	2.62	2.58	1.40

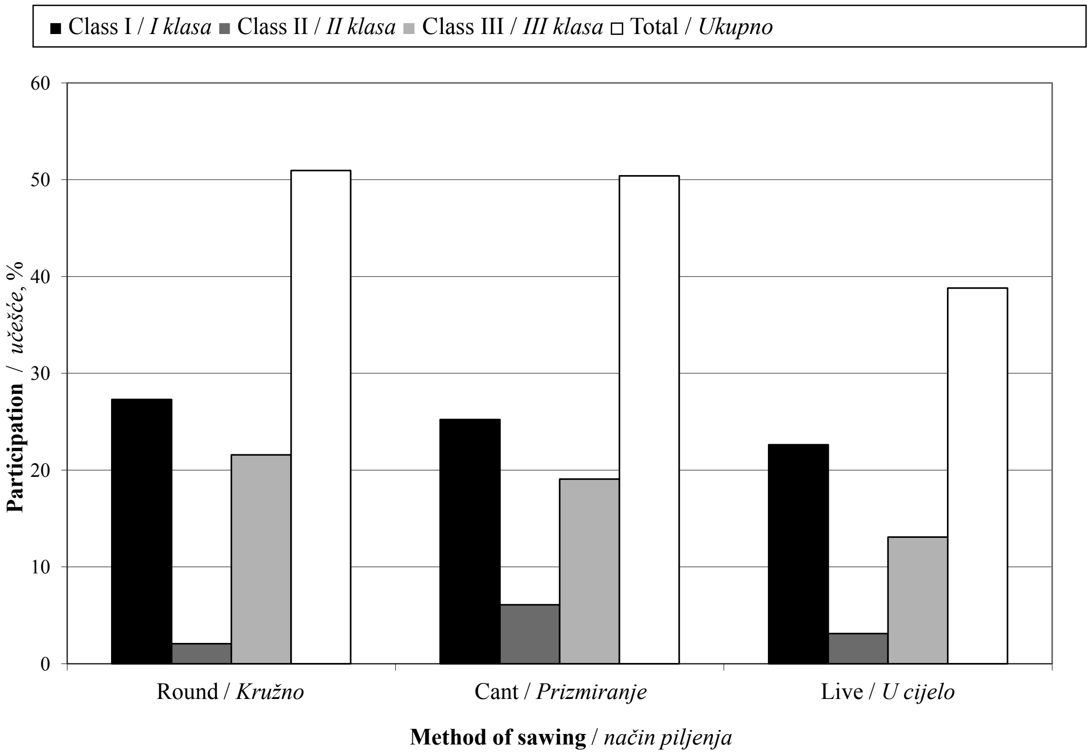

Figure 4 Quality structure of timber for different methods of beech logs sawing
Slika 4. Kvalitativna struktura piljene građe pri različitim načinima piljenja bukovih trupaca

through values of products per 1 m^3 of logs, and the coefficient of value increase (c_{vi}).

It is noticeable that the highest value of products per 1 m^3 of logs was achieved by cant sawing, and the lowest – by live sawing. However, variations of data were high (standard deviation in cant sawing was around 21 €/m^3 of logs), so the differences between methods of sawing were not proven (F=2.153, p=0.129).

When making the assessment of value yield by value increase coefficient, besides the values of logs and timber dimensions, the amount of work is also taken into account. There is a significant difference between the coefficients of value increase (F=6.897, p=0.003). Post-hoc comparisons showed that there is no difference between tangential methods of sawing, but they had a significantly higher value yield than live sawing. This difference is mainly caused by the coefficient of processing complexity, which amounted to 1.04 for round sawing and 0.94 for cant sawing, but only to 0.59 for live sawing.

4 CONCLUSION
4. ZAKLJUČAK

Comparing the quantitative and qualitative yields of beech logs sawn by the three methods (round, cant and live), it can be concluded that live sawing yielded the least favorable results, while other two methods yielded similar results. Quantitative yield in round sawing and cant sawing of beech logs was around 60.5 %, whereas in live sawing it was nearly 4 % lower (56.8 %). Structures of large and small waste products were equal in all the methods used.

The structure of products was strongly influenced by methods of sawing. It was most favorable in cant sawing, and least favorable in live sawing. Cant sawing yielded most timber, which is especially important for most valued products, that is, long edged timber. Live sawing yielded the highest amount of small sawmill products as compared to other two methods, and the share of red heart boards was the lowest because this product was produced by more precise, secondary machines.

In all three methods, the most frequent boards of all boards made of sapwood were the flat-sawn boards, rift-sawn boards were almost half as frequent and the presence of quarter-sawn boards was negligible, except in live sawing. This was as expected, considering the quality zones in beech logs, as well as the fact that the majority of quarter-sawn products were classified as red heart boards.

Round sawing yielded more timber of quality class I than other methods, but the most favorable structure was reached by cant sawing (production of more valuable products). Therefore, the value yield of these two sawing methods was equal, while live sawing yielded the lowest-value products.

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Analysis of Human Needs in Kitchen Design for People with Visual Impairment

Analiza ljudskih potreba pri dizajniranju kuhinje za slijepe osobe

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ABSTRACT • *In the modern society, about twenty percent of the population has problems with eyesight. As a result of the ageing process, it is expected that till the year 2020, the problem of visual impairment will be experienced by an increasing number of people. There is a relationship between impaired vision in old age and reduced quality of life and increased risk of dangerous situations in the kitchen. This paper is an attempt to meet and describe the desires and needs of people with visual impairment. The presented results of the survey research conducted among people with sight problems are the basis for the elaboration of design concepts for kitchen furniture. This paper describes the selected solutions of kitchen furniture designed for people with visual impairment to increase their comfort of living.*

Key words: *kitchen furniture, design for elderly people, visual impairment*

SAŽETAK • *U suvremenom društvu problem oštećenja vida obuhvaća populaciju od 20 % ljudi. Kao rezultat procesa starenja, očekuje se da će do 2020. godine problem slabovidnosti iskusiti sve veći broj ljudi. Postoji veza između oštećenja vida u starijoj dobi i smanjene kvalitete života, kao i povećane opasnosti s kojom se osobe suočavaju u kuhinji. Rad je izrađen s ciljem prikupljanja želja i potreba osoba oštećeniog vida. Prezentirani rezultati ankete provedene među osobama s problemima vida služe kao osnova za dizajnerski koncept kuhinjskog namještaja. Opisana su rješenja oblikovanja kuhinjskog namještaja namijenjenoga osobama oštećena vida radi omogućivanja udobnijeg života.*

Ključne riječi: *kuhinjski namještaj, dizajn za starije osobe, slabovidne i slijepe osobe*

1 INTRODUCTION
1. UVOD

The problem of disability can affect anybody. The constantly increasing number of the disabled is caused by several factors, including e.g. civilization-related diseases, road accidents, effects of environmental degradation, as well as the aging process. Assuming that almost everybody suffers from some dysfunction at a certain time in their lives, it is advisable to consider all disabilities and by addressing the needs - to create the conditions in which the disabled may also properly and fully function.

The importance and weight of this problem is indicated by the fact that, as reported by Balcerzak-Paradowska (2002), over 500 million people worldwide are suffering from different forms of disability. Visual impairment and blindness affect over 285 million indi-

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viduals worldwide (Pascolini and Mariotti, 2012). According to the data of the Main Statistical Office (Ciecieląg *et al.*, 2006) the number of individuals with visual impairment in Poland is over 1.7 million, making visual impairment the third most common cause of disability in Poland (29.5 %). It needs to be stressed here that this form of disability affects most frequently (36.5 %) the elderly (over 60 years of age) (GUS, 2006). Also Pascolini and Mariotti (2012) reported that 82 % of all blind individuals are over 50 years old. It is of particular importance, since it is estimated that by the year 2050 every fifth individual will be at least 60 years old (United Nations, 2007). Similarly as in other European countries, also in Poland the mean life span increased from 40 years in 1900 to approx. 80 in 2000 (Lewandowski, 2000), and consequently the number of people suffering from different forms of disability is also increasing (Freedman and Martin, 1998; Hrovatin *et al.*, 2012). Literature data report that in the year 1988 every tenth inhabitant of Poland was classified as disabled (Kowal, 2002). The number of individuals with some impairment in 1988 reached approx. 3.7 million, while in early 1993 it was over 4.5 million, accounting for approx. 11.6 % of the total population, whereas in 2004 it was already over 6.2 million (GUS, 2006).

The increasing number of the disabled imposes the obligation on furniture designers to search for solutions that would at the same time combine elegance, comfort and meet the basic safety requirements. Such solutions are characteristic of more complex design methods based on ergonomics. The interdisciplinary character of this field makes it possible to create furniture products fully adapted to the user's needs, both physically and emotionally (Świątek, 2001).

Modern furniture designed for the disabled is primarily focused on individuals with limited motion capacity. Design products are usually not aimed at meeting the needs of individuals with visual impairment.

As a consequence of aging of the population in developed countries, the problem of visual impairment will affect an increasing number of individuals. It is essential to undertake studies on the identification of needs of this group of users, particularly as it has been proven that there is a strong dependence between visual impairment at an older age and a lower standard of living and greater probability of accidents (Evans and Rowlands, 2004). Also Acimis *et al*. (2009) highlight the higher risk of dangerous situations occurring in older age.

Thus the aim of this study was to collect information concerning both preferences and problems faced by the elderly or middle-aged individuals with visual impairment when working in the kitchen. An additional practical objective was to propose examples of ready design solutions for kitchen furniture for individuals aged 65+ with visual impairment.

2 MATERIAL AND METHODS
2. MATERIJALI I METODE

By using questionnaires and interviews, data were collected concerning the needs, habits and problems faced by the blind or people with low vision when using the kitchen,. The assumed population size was 100 individuals suffering from different forms of

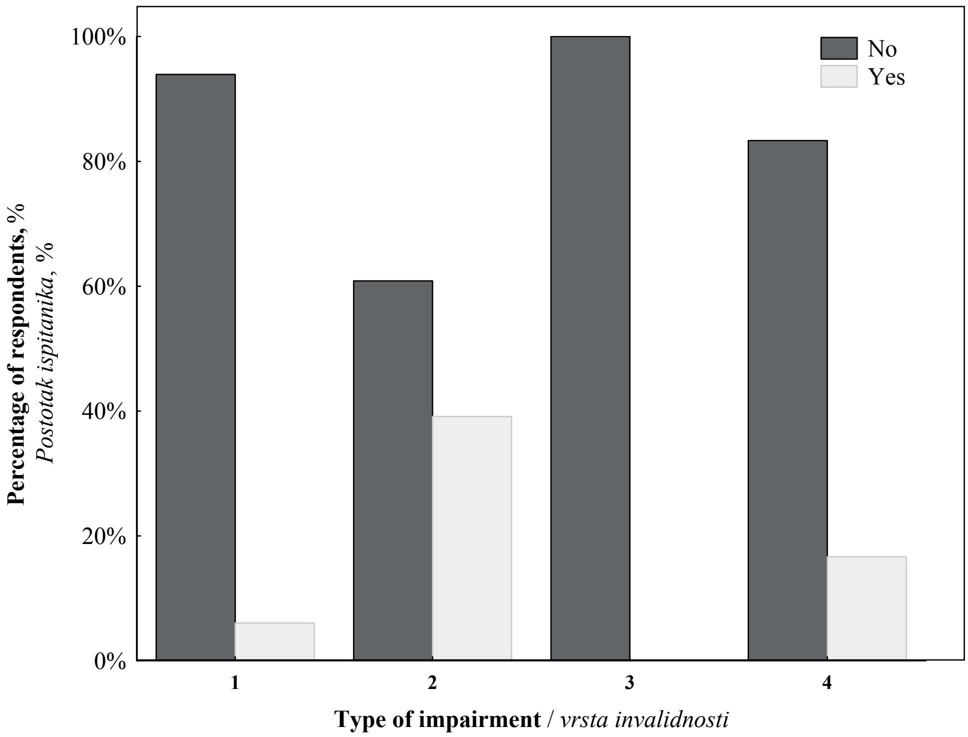

Figure 1 The structure of furniture adaptation depending on the type of disability of respondents (VI – Visual Impairment) – Blind, 2 – partly sighted, 3 – VI and wheelchair, 4 – VI and crutches etc.
Slika 1. Struktura prilagodbe namještaja vrsti invalidnosti ispitanika (VI - oštećenja vida) - slijepe osobe, 2 - osobe djelomično oštećenog vida, 3 - slabovidne osobe u kolicima, 4 - slabovidne osobe sa štakama

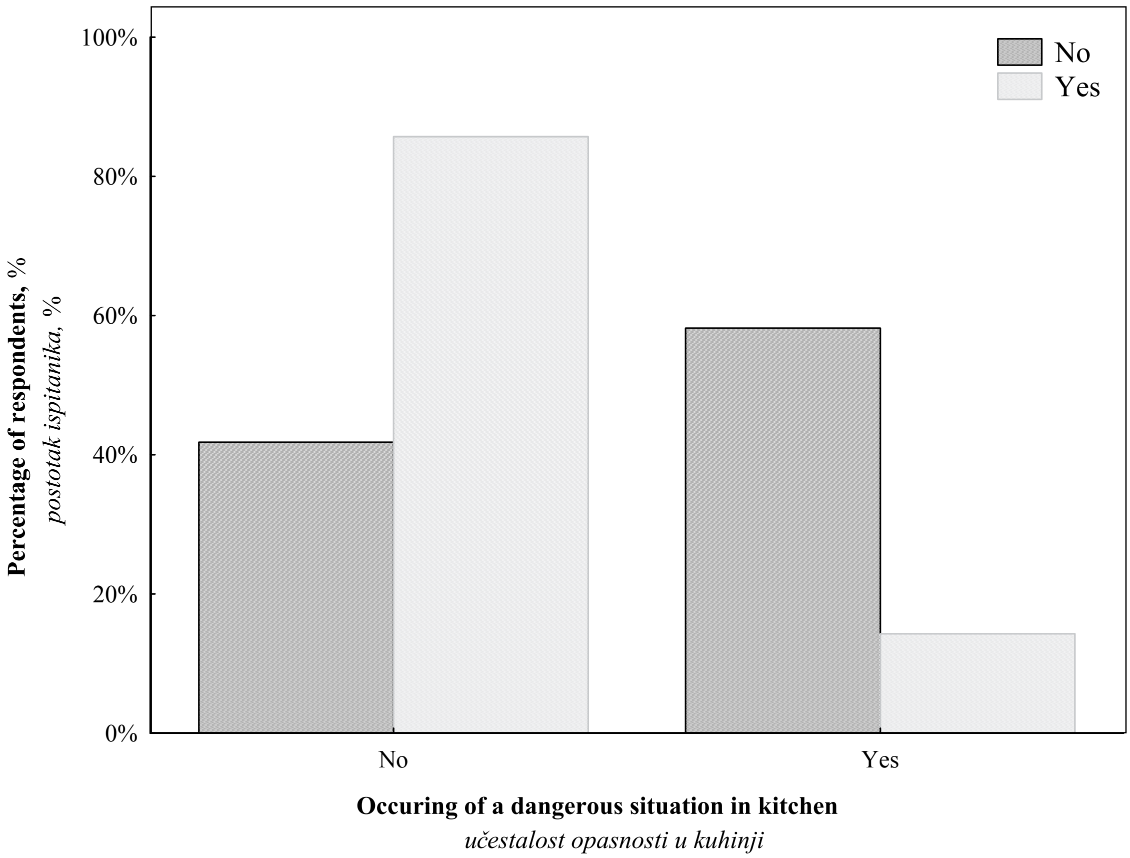

Figure 2 The relationship between the adaptation of kitchen furniture to user disability and dangerous situations occurring in the kitchen
Slika 2. Odnos između prilagodbe kuhinjskog namještaja invalidnosti korisnika i pojave opasnosti u kuhinji

visual impairment. The questionnaire consisted of closed, open and semi-open questions. The subject covered problems concerning the use of the kitchen by individuals with visual impairment, basic information on the respondents participating in the study, identification of dangerous situations when performing individual activities connected with meal preparation, evaluation of kitchen furniture in their possession as well as information on the needs and preferred changes in kitchen furnishings.

Collected data were coded and subjected to comprehensive statistical analysis. Results of the investigations constituted the basis for the development and proposals of new solutions for kitchen furniture, which could potentially enhance the comfort of living for the analyzed group of individuals. They were presented using the Autodesk Inventor® program.

3 RESULTS AND DISCUSSION
3. REZULTAT I RASPRAVA

Taking into consideration the percentage of returned questionnaires, their completeness and the number of direct interviews, it was decided to conduct further analysis based on data coming from 88 respondents. The results of the conducted investigations show considerable need to provide kitchen furniture designed for individuals with visual impairment. This stems from the fact that as many as 76 % people in the analyzed group of respondents do not have kitchen furniture adapted to their needs connected with their dysfunction. Figure 1 presents the structure of furniture adaptation to user needs depending on the type of disability of respondents.

A relationship is identified between the adaptation of kitchen furniture to users' disability and dangerous situations occurring in the kitchen (Figure 2).

For the analyzed variables, the independence Pearson test χ^2 was conducted. The hypothesis 0 was verified: H_0: variable X (furniture is adapted to disabled person needs) and variable Y (occurring of dangerous situation) are independent versus alternative hypothesis H_1: variables X and Y are not independent. The results of the test indicate that this relationship is statistically significant at the level p=0.00044 (χ^2=12.36), meaning that the variables are dependent.

Therefore, it should be emphasised that it is necessary to design furniture specifically for the needs of disabled people in order to minimize the probability of accidents in the kitchen. This is extremely important since dangerous situations happened in 48 % of the analysed cases.

Dangerous situations resulting from the use of kitchen furniture with obstacles, which need to be overcome by a person with a visual impairment when staying in the kitchen, are shown in Figure 3. An analysis of the figure below shows that, next to burns (51 %) and cuts (33 %), some of the more frequent dangerous

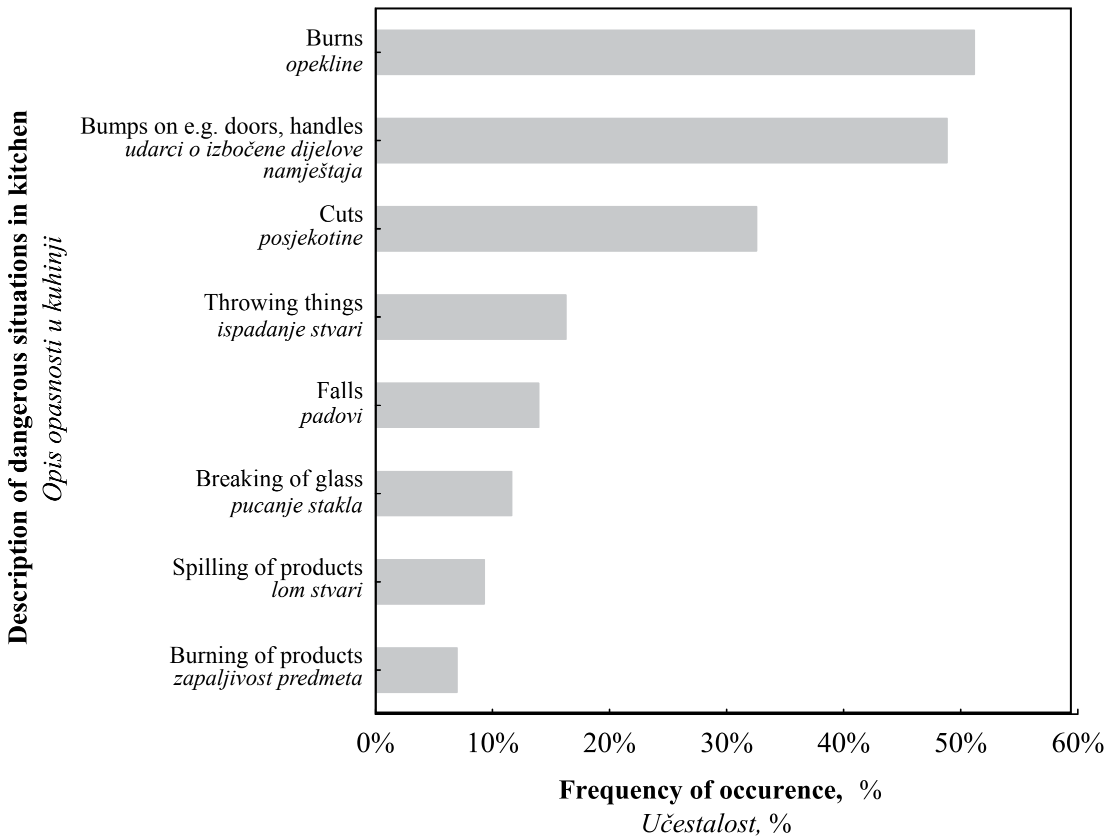

Figure 3 Dangerous situations in kitchen
Slika 3. Opasnosti u kuhinji

situations occurring in the kitchen include e.g. bumps into doors of upper cabinet, sharp edges or protruding handles (43 %). In view of the above, it would be justified to replace traditional doors with a vertical axis of rotation with sliding doors or doors opening in the vertical plane, as well as redesign furniture handles and knobs. The importance of the problem of bumping into doors or corners was also pointed out by Hrovatin *et al.* (2012). It was indicated in the research that as much as 72 % of elderly persons faced at least once that dangerous situation.

In direct interviews a large number of respondents pointed to the problem of loss of balance when performing everyday activities. It is estimated that the elderly people and individuals with low vision fall twice as often as people with normal vision (Evans and Rowlands, 2004). The problem of balance disturbances of the elderly was also indicated by Kabsch (2000), who stressed that mortality caused by fall accidents increases drastically after 70 years of age (Kabsch, 2003; Web-based Injury Statistics…, 2004). Moreover, the results of studies conducted by the Department of Furniture Design, Poznan University of Life Sciences, show that among 136 individuals aged over 51, falls account for 38 % of all dangerous situations in the kitchen. According to Stevens (2005) 30 % of users over 65 experience a fall in their kitchen each year.

Based on the analysis of data presented in Figure 3, safer solutions can be designed taking into consideration the needs of people with visual impairment. Thies is important since, for example, Nevitt *et al.* (1989) pointed out that environmental factors do play a part in about half of all home falls. Proposals as how to avoid dangerous situations in the kitchen and at the same time the basic design criteria are given in Figure 4. Special attention was focused on modifications of the existing range of furniture, resulting in greater rounding of worktops and element of subassemblies (29 %). Respondents pointed to the necessity of replacing traditional doors with a vertical axis of rotation with sliding doors in order to completely eliminate the risk of a bump (9 %) as well as replacing standard handles with recessed handles (7 %). The need for arranging the kitchen with furniture without handles and equipped with sliding doors was also highlighted by Hrovatin *et al.* (2012). The respondents would like to have induction cook tops in their kitchens; however, instead of sensory control they should have manual control (e.g. knobs) (20 %), since they are easier to operate according to respondents.

The analysis was based on data collected from respondents concerning their individual expectations for the optimal aesthetic and design solutions in kitchen furniture. Respondents declared that the furniture of their dreams should first of all be functional (24 %) and equipped with furniture hardware preventing bumps (14 %). A lot of attention was also paid to the dimensions of furniture adapted to user needs and use of ma-

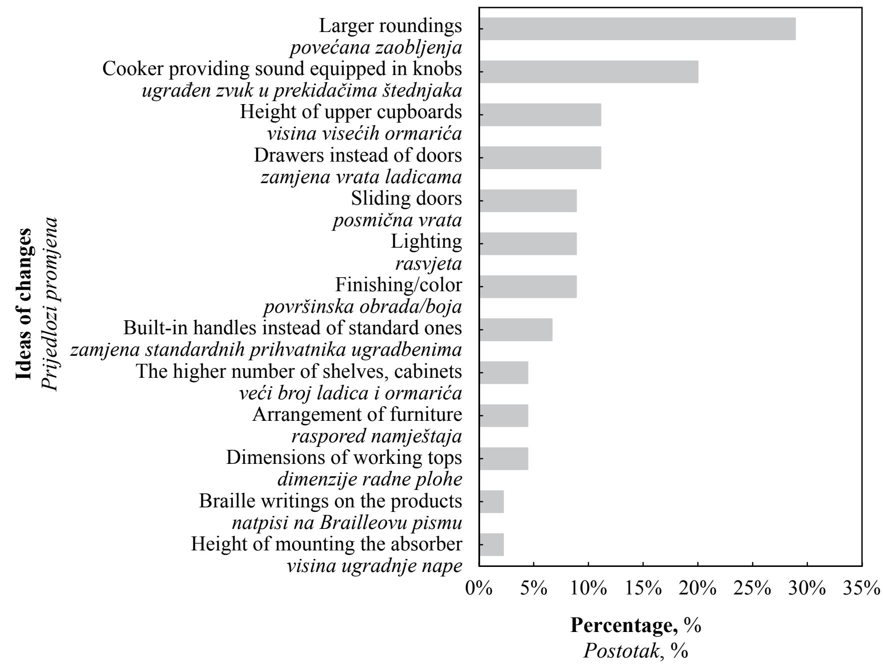

Figure 4 Modifications to be made in kitchen furniture according to respondents
Slika 4. Preinake koje bi ispitanici napravili na svome kuhinjskom namještaju

terials resistant to dirt and scratches. Further to the above, functional and safe furniture, fully adapted to the needs of the future user, should be made.

3.1 Selected solutions of kitchen furniture designed for people aged 65+ with visual impairment
3.1. Odabrana rješenja dizajna kuhinjskog namještaja prilagođenoga osobama oštećenog vida starijim od 65 godina

On the basis of questionnaire surveys and direct interviews, a set of guidelines was developed for the design of kitchen furniture for individuals 65+ with visual impairment. This constituted the basis for the development of the design solutions presented below.

Two groups of hanging cabinets were proposed, with a width of 600 mm and 1000 mm (Figure 5), consisting of a non-standard solid frame, with sides at the angle of 85º, providing adequate lighting for the worktop, additionally to light coming from the ceiling. This is crucial, since the results of Taha and Sulaiman (2010) indicate that kitchen brightness level was lower than required by the elderly, which could affect their task performance. Moreover, according to Hrovatin *et al.* (2012) the amount of inadequately lit kitchens among seniors is 32 % in Slovenia and 25 % in Italy (Colombo *et al.,* 1998). In the modern concept of kitchen furniture, the fronts are additionally equipped with handle strips. The long handle, placed almost along the entire width of the front, is an improvement for the blind and individuals with low vision as this enables them to quickly find, identify and open a cabinet. The front design is supplemented with a space identifier, containing the full name of objects found inside the cabinet in Braille (Figure 5, Figure 8). Furthermore, inside the cabinet, lighting is fitted with a movement detector, as suggested by many respondents.

As mentioned above, approx. 49 % of respondents declared that bumping into the furniture front is one of the most frequent dangerous situations in the kitchen. It was decided to eliminate this danger by mounting, in the frame, the fittings elevating the front in vertical position (Figure 6).

Concerning the worktop standing cabinets, it was proposed to provide finishing characterised by a special structure and contrasting colour, which might be

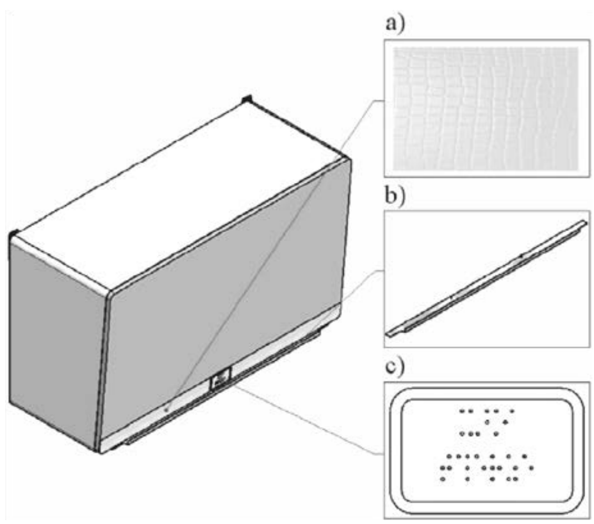

Figure 5 A hanging cabinet with improvements: a) covering, b) handle, c) the Braille space identifier
Slika 5. Viseći ormarić s poboljšanjima: a) pokrov, b) prihvatnik, c) oznaka na Brailleovu pismu

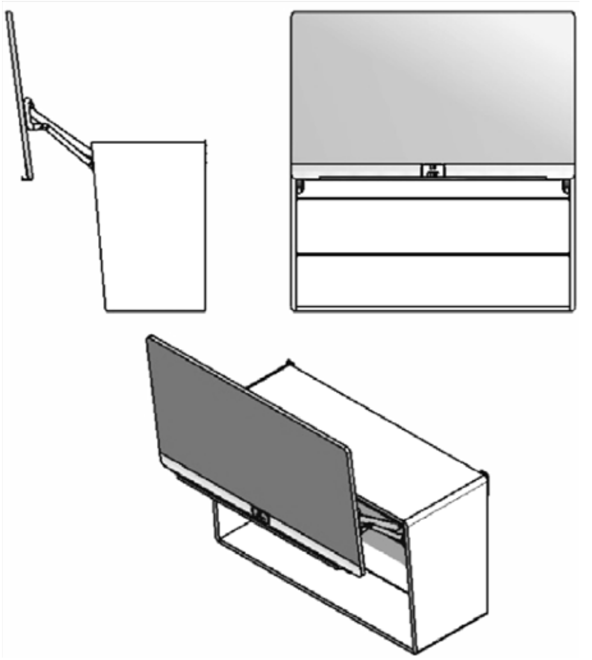

Figure 6 The method to open a hanging cabinet
Slika 6. Način otvaranja visećeg ormarića

helpful in the identification of the board margin and minimise the number of dangerous situations. Kowalski (2008) pointed to the fact that the contrast and colour are important aspects in the design of interiors adapted to the needs of individuals with visual impairments. Following the recommendations of respondents, the designed cabinets were equipped with drawers, from which standard, commonly used handles were removed and replaced with handles integrated with the front, made along their entire width (Figure 7). Similarly as in case of hanging cabinets, the Braille space identification system was applied on the front of every drawer. The base was removed from the front plane of the cabinet at a foot's length. This is to provide easy movement around the kitchen and prevent collisions between the user and furniture. Fronts of bottom drawers are composed of two elements, of which one is placed at an appropriate angle to the floor. The function of such a placement of bottom drawer fronts is to prevent legs hitting the front of the drawer when moving along the edge of the furniture to the next work position.

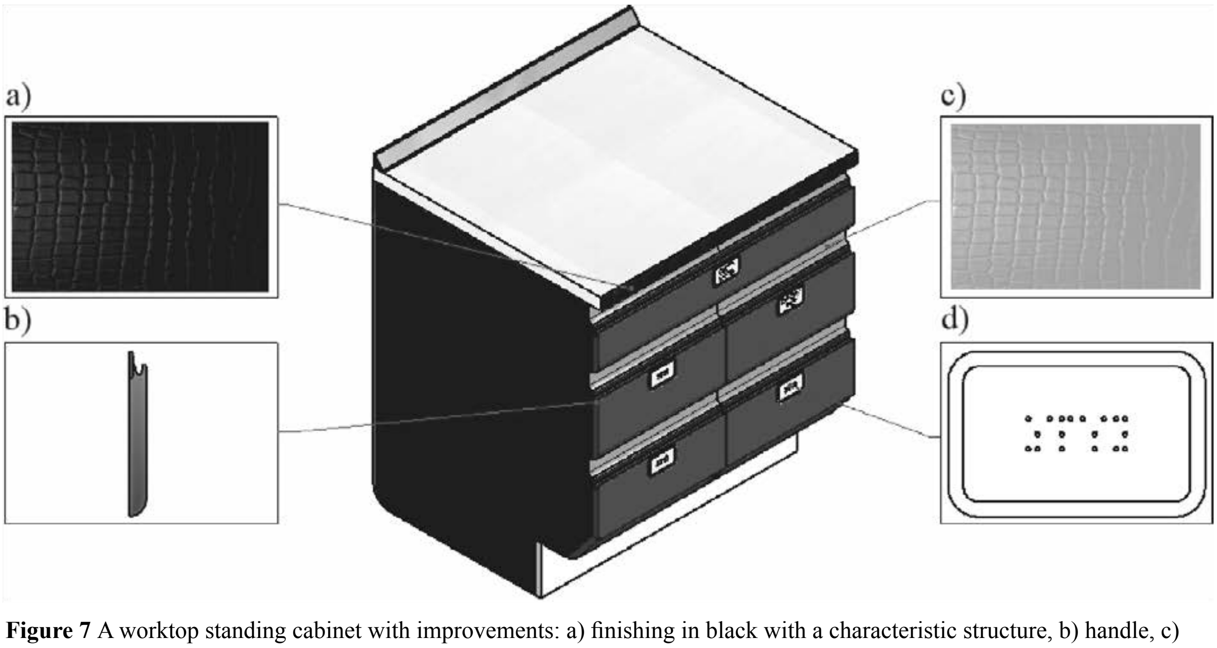

Figure 7 A worktop standing cabinet with improvements: a) finishing in black with a characteristic structure, b) handle, c) finishing in a light colour with a characteristic structure, d) the Braille space identifier
Slika 7. Preinake donjeg ormarića s radnom pločom: a) površina je crna i reljefna , b) upušteni prihvatnik, c) površina svijetle boje i karakteristične strukture, d) identifikator sadržaja ormarića na Brailleovu pismu

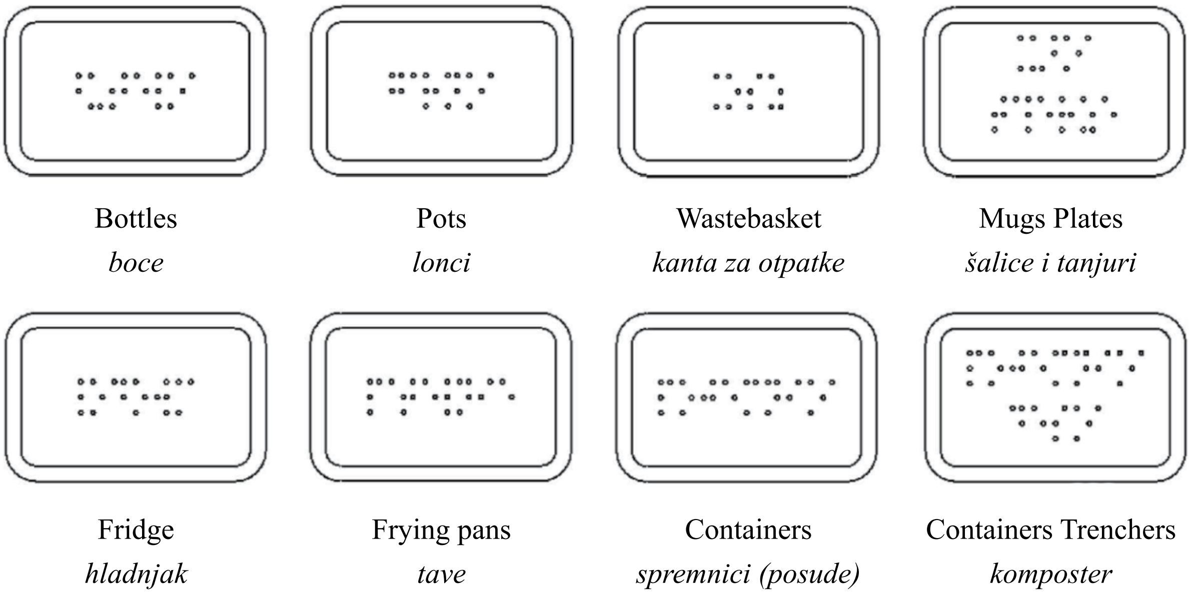

Figure 8 Space identifiers with examples of names of objects in Braille
Slika 8. Identifikator sadržaja ormarića ispisan Brailleovim pismom

In order to limit all types of cuts, indicated by the respondents as frequent dangerous situations in the kitchen (Figure 3), it was decided to place all kitchen cutting tools in special holders in drawers. The same was done with all other kinds of cutting tools. An example solution is presented in Figure 9.

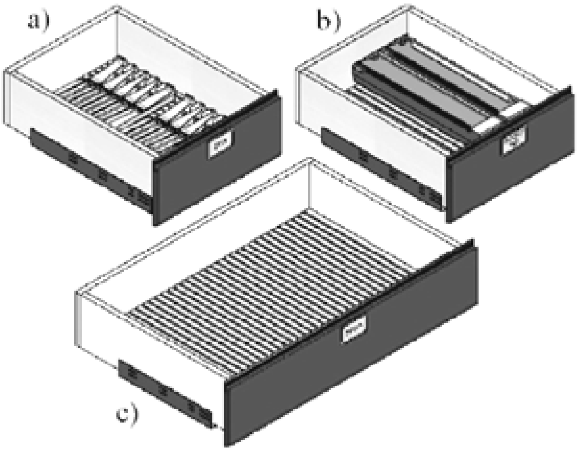

Figure 9 Middle drawers with fittings: a) a single drawer with knife holders, b) a single drawer with a foil cutter, c) a single drawer with anti-slipping mat
Slika 9. Unutrašnjost ladice s opremom: a) ladica s ležištima noževa, b) ladica s rezačem folije, c) ladica s protukliznom podlogom

Drawers with high fronts and selected types of upper drawers may be a combined system (cargo cabinets) (Figure 10), increasing the functionality of kitchen furniture.

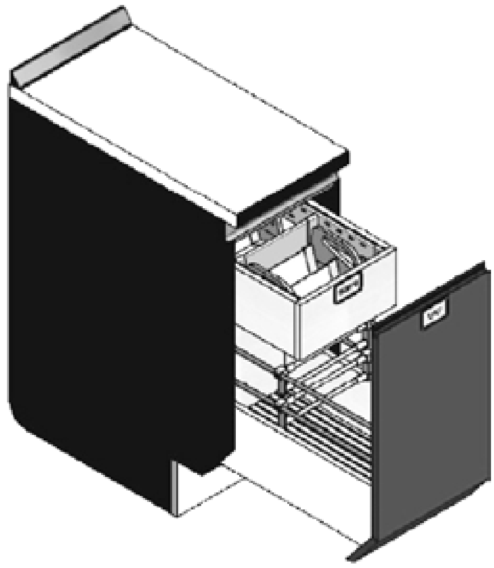

Figure 10 A Cargo standing cabinet
Slika 10. Donji ormarić tipa *cargo*

4 CONCLUSIONS
4. ZAKLJUČAK

As a result of questionnaires and direct interviews, important information was gathered to facilitate designing furniture for elderly people with visual impairment. The results can be used as guidelines for designing ergonomic kitchen concepts fully adapted to the user needs.

Further to the above, the following solutions are recommended:

1. To mount the fittings for elevating the front in vertical position or for sliding doors in the frame of upper cupboards in order to eliminate bumping into open doors.
2. To fit the cabinets with handles integrated (built-in) with the front in order to avoid bumping into protruding furniture handles.
3. When designing furniture for people with visual impairment, to use veneers (coverings) with contrast colour and special structure easy to feel and recognize by touching. It is also recommended to introduce Braille identifiers on the furniture fronts describing the cabinet content.
4. To place all cutting tools in safe drawer holders in order to limit cuts.
5. To equip the kitchen with full extension cargo cabinets in order to increase the functionality of furniture. This solution not only allows easier access to the products stored but also well-lighted cabinets.

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Factoring and Forfeiting in Slovakia and Possibilities of its Application in Wood-Working Industry

Factoring i *forfeiting* u Slovačkoj te mogućnosti njihove primjene u drvoprerađivačkoj industriji

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ABSTRACT • *Factoring is the contract negotiated continuous purchase of short-term debts, incurred by supplier due to the provision of unsecured credit supply. Factoring is a method of financing that can offer a lot to businesses, especially with its added value. This method mainly includes protection before customers' insolvency, management of receivables, as well as the opportunity to dispose with the funds before the end of the maturity of receivables. Forfeiting is the purchase of export receivables on credit at the time of delivery. It is related to receivables with the future maturity denominated in freely convertible currency, and secured with a bank aval bill, letter of credit with deferred payment or a bank guarantee. The conditions, under which each company provides forfeiting, depend essentially on the creditworthiness of the applicant and customer, as well as creditworthiness of the bank that issued the payment instrument. The aim of the present paper is to analyze the factoring and forfeiting market in Slovakia and based on the analysis of this issue to propose and verify theoretical and practical possibilities of factoring and forfeiting financing in the selected wood-working company with the estimation of costs associated with their use.*

Keywords: *factoring, Association of Factoring Companies, forfeiting, receivables, purchase of receivables, discount*

SAŽETAK • *Factoring je daljnje trgovanje kratkotrajnim dugovima dogovoreno ugovorom, u sklopu kojega se dugovi prenose na dobavljača u obliku pribavljenoga neosiguranog kredita. Factoring pripada metodama financiranja, a često se nudi poslovnim sustavima, posebice s višom dodanom vrijednosti. To je metoda koja podrazumijeva zaštitu prije insolventnosti kupca ili korisnika usluga, odnosno upravljanje zahtjevima, kao i mogućnost da se raspolaže sredstvima prije dospijeća zahtjeva. Forfeiting je trgovina potraživanjima davanjem kredita u vrijeme isporuke. Vezan je za potraživanja koja će u budućnosti dospijevati i koja su denominirana u slobodnoj konvertibilnoj valuti te osigurana bankovnom mjenicom, kreditnim pismom ili bankovnim jamstvom. Uvjeti uz koje pojedina kompanija nudi forfeiting ovise isključivo o kreditnoj sposobnosti onoga koji se prijavljuje i kupca, odnosno korisnika usluga, kao i o kreditnoj sposobnosti banke koja izdaje dokumente o jamstvu. Cilj ovog rada jest analiziranje tržišta factoringa i forfeitinga u Slovačkoj kako bi se na temelju te analize, sa stajališta teorije i prakse,*

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predložila i potvrdila mogućnost financiranja pojedinih kompanija u preradi drva i proizvodnji namještaja factoringom i forfeitingom, uz procjenu troškova vezanih za njihovu primjenu.

Ključne riječi: *factoring, udruženje factoring kompanija, forfeiting, potraživanja, trgovina potraživanjima, diskont*

1 INTRODUCTION
1. UVOD

In the business world, companies are constantly faced with uncertainty. Reducing these uncertainties and ambiguity with good sale forecasting represented a big problem for the companies (Oblak *et al*., 2012)

For all enterprises, whether small, medium or large, the issue of financing their business activities is very significant. Many different bank loans are offered on the market, but banks are very careful in providing them in these times. Apart from standard forms of financing, enterprises can use alternative methods such as leasing, venture capital, factoring and forfeiting. Forfeiting and factoring are the tools of receivables management that allow the funding and coverage of their risks (Novakova R., 2004).

Factoring is not only financing of receivables with deferred payment, but it offers much more. It is mainly the management of receivables, reminder service and related recovery of outstanding debts, especially when small and medium size enterprises can outsource these activities to a factoring company, which can carry out these functions more efficiently (Potkány, 2010).

Forfeiting is the purchase of export receivables on credit at the time of delivery. It is related to receivables with the future maturity denominated in freely convertible currency, and secured with a bank aval bill, letter of credit with deferred payment or a bank guarantee. The conditions, under which each company provides forfeiting, depend essentially on the creditworthiness of the applicant and customer, as well as the creditworthiness of the bank that issued the payment instrument. For making a forfeiting transaction, a minimum amount of receivables is required – in current practice a minimum limit of the claim is usually 200 000 USD and minimum maturity period is 90 days (Grúň, 1997). Therefore, forfeiting indicates the purchase of medium- and long-term receivables arising from export and also from import, while the receivables purchasing entity (forfeiter), usually a bank or financial institution, has not the opportunity to urge the recourse to the exporter if the claim is not properly and timely paid by the importer. Forfeiter sets its own conditions determining the situation on the market and its own estimates of the risks associated with individual transactions (Novakova, R., Kusy, O., 2010). The exporter gets his claim paid by the forfeiter; and the credit risk (the risk of default), as well as any additional risks (currency, interest rate, political, etc.) associated with the claim, pass to forfeiter.

The aim of the present paper is to analyze the factoring and forfeiting market in Slovakia and based on the analysis of this issue to propose and verify theoretical and practical possibilities of factoring and forfeiting financing in the selected wood-working company with the estimation of costs associated with their use.

2 MATERIALS AND METHODOLOGY
2. MATERIJALI I METODA

The methodology closely corresponds to the aim of the present paper. The following methods were used: description method, analysis and synthesis of information related to theoretical definition of factoring and forfeiting.

The method of analysis was used by mapping of the factoring market in Slovakia based on information of the Association of Factoring Companies (AFC) in the SR

Then we have compared the basic conditions (minimum annual turnover, number of customers, factoring fee, interest paid in advance and maturity of receivables) at the VÚB Factoring a. s., Factoring ČSOB, a. s. and Factoring SLSP, a. s. and summarized these data to make the final comparison.

We approached all the above-analyzed factoring companies with the aim to propose factoring financing to a purchaser of the selected wood-working company. It is a new customer, with invoices due up to 90 days. Given the fact that the selected wood-working company had no experience with this new customers and the maturity of invoices was 90 days, we proposed to use domestic non-recourse factoring with participation. This is the way of receivables repurchasing, where the factoring company takes over the risk of customer non-payment of receivables due to the insolvency or unwillingness to pay. We evaluated the indicative offers of the selected factoring companies by methods of analysis and comparison and recommended the best ones.

The method of analysis was also used in mapping the forfeiting market in Slovakia. The results are based on the method of information synthesis. We have proposed and verified the possibility of forfeiting financing in the selected wood-working company with the calculation of the associated costs. For the calculation of the forfeiting costs, we selected a convenient foreign customer by the method of selection; we defined the basic conditions for the purchase of receivables, and then we calculated the discount interest and front-end fee, which represent the cost of forfeiting in our case.

Factoring is the contract negotiated continuous purchase of short-term debts, incurred by supplier due to the provision of unsecured credit supply. The factoring company then often downloads risks associated with outstanding receivables. The subject of factoring can be these receivables, which arise solely from the sale of unsecured loans with the duration of maximum180 days (Grun, 1997).

The receivables that meet the following characteristics can be purchased:
- maturity of receivables shall be maximum 180 days,
- receivables shall arise from unsecured credit supply,
- they shall not be associated with any other third party rights (for example set-off receivables),
- receivables shall have acceptable credit ratings and come from an acceptable state (Dvorak, 1997).

An important part of the factoring operation is the determination of its costs. Concerning the fees, factoring is a transparent transaction. It is always paid only for services used by the client, and the total cost corresponds to the real scope of cooperation (Hyránek and Bikar, 2010).

When using factoring, the following costs arise:
a) Interest - factoring company charges them for the actual expenditures. Interest rates are on the level of the current bank overdrafts and are linked to the reference interest rates on the interbank market.
b) Factoring fee – it is the cost that the factoring company charges for a full takeover of receivables management including the monitoring of customers and ensuring of receivables encashment, as well as the reminder service.
c) Fee for taking default risk– it is a part of the factoring fee. The fee is determined individually as a percentage of the total value of transferred receivables.

An early use of forfeiting was recorded in the Middle Ages. This technique particularly flourished in the 60's of the last century, when the centrally planned economy of socialist countries needed to finance a major capital equipment import from Western Europe and exporters feared the risk (cross-border risk), so they first involved their banks into the process. In the banks, the Department of Trade Finance deals with these transactions. Some of these departments have gradually become independent and founded independent forfeiting companies. These companies were owned by large banks, whose financial strength was what the companies needed and their activities were supplementary. Thus forfeiting has been developed only in recent decades and when compared with leasing or factoring, it is the youngest alternative form of financing.

As Hyránek and Bikar (2010) outlined, several types of forfeiting have been developed in practice:
- Export forfeiting – it is the most common type of forfeiting and is associated to export. An exporter, who exports abroad and wishes to have its receivables paid from abroad, before the foreign purchaser is willing to pay, negotiates with forfeiter the ways and conditions of forfeiting the claim. If the agreement of both parties is set up, the forfeiter pays to exporter the claim and then he collects payment from a foreign purchaser at the time of its maturity.
- Import forfeiting – it is based on financing of import and can occur in two variants:
  - Domestic importer imports the goods on supplier credit and forfeiter purchases the claim from foreign exporter. Exporter exports to a cash payment of forfeiter and importer receives the goods on supplier credit.
  - Domestic importer receives the goods on supplier credit from the exporter and he exposes a promissory note with aval of an acceptable domestic bank at the same time. He sells the promissory note to forfeiter, and this way he acquires the cash to pay the foreign supplier.
- Financial forfeiting - domestic company, witch is interested to obtain a foreign currency loan, issues a promissory note with aval of an acceptable domestic bank. Aval promissory note is sold to forfeiter, who pays for it immediately for the discount rate.

Certain costs are related to the forfeiting of receivables, which are in the price of forfeiting and are charged to forfeiter. The following items are reflected in the price (Kláseková, 2003):
1. Discount – it is the most important part of the forfeiting costs. It is an amount that forfeiter deducts from the total amount of the claim by its purchase. The amount of the discount rate for each forfeiting case depends on several factors, such as: the risk of importing country, debt maturity, currency, creditworthiness of the bank liability cover and others. The discount rate is usually based on current interest rates on the interbank market (usually 1 or 3 - month Euribor).
2. Commitment fee – it is a provision that the forfeiter charges for the holding of quick money in the period from agreeing of the forfeiting contract to the sale of payment instruments. It is usually determined as a percentage on an annual basis and it is payable monthly.
3. Front-end fee – it covers the cost of forfeiter for the processing of the forfeiting case and its amount depends on the overall complexity.
4. Option fee – it is charged to forfeiter in the case when an exporter has obtained an option for forfeiting contract for a specified period (usually longer than one month) for fixed conditions. Option fee is usually charged as percentage of the amount of the forfeiting claim and it is paid as a single payment in advance.

Receivables that are the subject of forfeiting operation, and that are purchased, must meet the following requirements (Hyránek and Bikar, 2010):
– receivables shall be provided by own or foreign draft (which is guaranteed by bank), by letter of credit or bank guarantee,
– maturity of receivables shall not be less than 90 days,
– receivables shall be in freely convertible currencies (EUR, USD, GBP, CHF).

A summary of advantages and disadvantages of forfeiting is presented in Table 1.

Table 1 Summary of advantages and disadvantages
Tablica 1. Pregled prednosti i nedostataka

Advantages / *Prednosti*	**Disadvantages /** *Nedostaci*
transfer of risks (political and commercial), associated with payment of transfer claim to forfeiter */ prijenos rizika (politički i tržišni), koji je povezan s plaćanjem prijenosa potraživanja na forfietera*	- cost of the forfeiting contract / *troškovi pri realizaciji ugovora o forfeitingu*
provides possibility of transferring the supplier credit to the customer / *daje mogućnost da se kredit dobavljača prebaci na kupca (korisnika)*	- minimum amount of each claim / *minimalni iznos pojedinog potraživanja*
reduction of receivables in the balance sheet / *smanjuje se iznos potraživanja u računu dobiti i gubitka*	- administrative difficulties / *administrativne teškoće*
improvement of financial indicators / *poboljšanja financijskih pokazatelja*	
flexible form of financing that does not increase the credit involvement of importer / *fleksibilni oblik financiranja kojim se ne povećava iznos primateljeva kredita*	
more competitiveness in obtaining contracts / *veća konkurentnost pri ugovaranju*	

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Factoring, as a developed form of business financing abroad, has developed rapidly in recent years in Slovakia, as evidenced by the growing turnover of factoring companies operating in our market. Slovak enterprises have discovered the advantages of this method of financing. The factoring added value is still not quite understood, meaning that factoring is not just about financing of receivables. Factoring financing supported the entry of Slovakia into the European Union, as well as the relative export orientation of Slovak companies (Hyránek amd Bikar, 2010). The ratio of factoring turnover to the GDP of economies was used for comparing the background and potential of the factoring market in individual countries. This ratio ranges from 2.8 % to 3.5 % in Slovakia, while in developed economies, it is from 8 to 12 %.

Activities of factoring companies are directed through the ASF in Slovakia. The market share of individual members of AFC in the year 2011 is presented in the following figure.

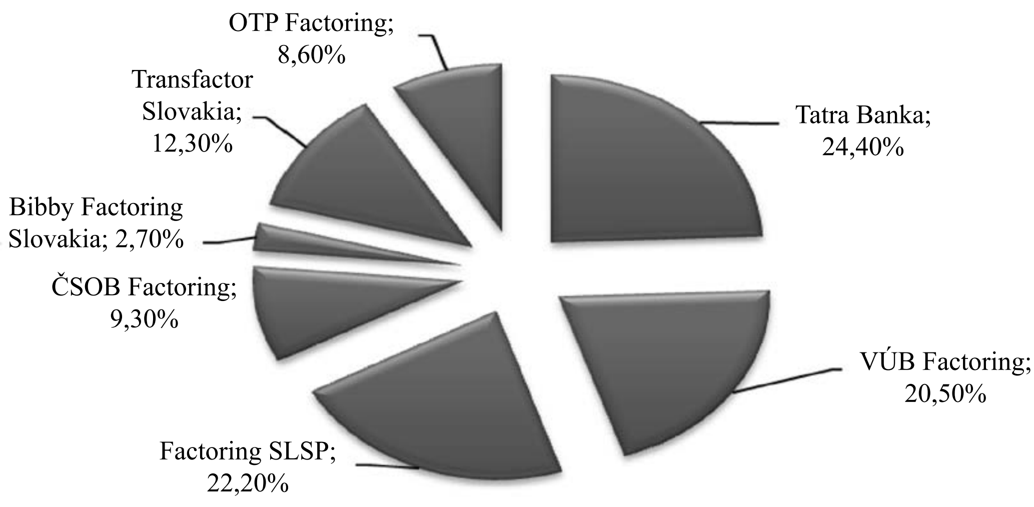

Figure 1 Market share of AFC members in 2011
Slika 1. Tržišni udio članova AFC-a u 2011.

As shown in Figure 1, factoring companies VÚB Factoring, a. s., ČSOB Factoring, a. s. and Factoring SLSP, a. s. are the four largest companies operating in Slovakia, as subsidiaries of large banking institutions and they account for 70 % of the total market share.

Summary comparison of the basic conditions and parameters of the three biggest factoring companies on the Slovak market are presented in Table 2.

Table 2 Summary comparison of the basic conditions and parameters of factoring
Tablica 2. Usporedni pregled osnovnih uvjeta i parametara *factoringa*

Factoring companies *Factoring kompanije*	**Minimum turnover per year** *Minimalni godišnji promet*	**Minimum number of purchasers** *Mininalni broj potraživanja*	**Factoring fee** *Trošak factoringa*	**Interest rate** *Kamatna stopa*	**Paid advance** *Plaćanje unaprijed*	**Maturity of receivables** *Rokovi plaćanja potraživanja*
VÚB Factoring	350 000 €	3	0.1 % - 1.5 %	1 M EURIBOR + 1,5 % - 4 %	70 % - 90 %	14 - 120 days / dana
ČSOB Factoring	1 mil. - 1,5 mil. €	3	0.2 % - 2 %	1 M EURIBOR + 2 % - 5 %	60 % - 80 %	standard to 90 days / *dana*
Factoring SLSP	500 000 €	3	0.3 % - 1.5 %	1 M EURIBOR + 1 % - 4 %	70 % - 90 %	14 - 120 days/ *dana*

3.1 Proposed factoring financing in the selected wood-working company
3.1. Prijedlog *faktoring* financiranja u određenoj tvrtki za preradu drva

The analyzed wood-working company was established in 2005 and has done its business in the primary production of wood. The company has a steady group of customers that offer the payment term from 30 to 60 days. The financial and economic situation of the company is good, except the liquidity indicator of the first level, which shows some problems with the company's solvency. The company has used overdraft and it drew 32 344 € from the total loan of 33 000 € to December 31, 2011. The company uses the overdraft to overcome the temporary shortage of funds. This usually happens when the company waits for the maturity of invoices.

To solve this temporary lack of liquidity, we proposed to the company in question the possibility of using factoring. The main reasons why the company should use factoring are:

- maturity longer than 30 days,
- permanent group of suppliers,
- re-delivery system based on commercial contract,
- smooth payment,
- minimum turnover,
- elimination of low liquidity problem.

One of the conditions for providing factoring in all three analyzed factoring companies is that each company has at least three purchasers. If the company decided to use this form of financing, its other customers would have to use factoring, too. Table 3 presents individual indicative offers and the basic parameters of factoring.

Concerning the advances, participation, interest rate and factoring fee, *the best indicative offer was given* to the wood-working company in question by *the factoring company VÚB Factoring, a. s.*

If the wood-working company decided to take this offer and the offer also passed other approval of VÚB Factoring, a. s. under the same conditions, the financing procedures and incurred costs would be the following:

Table 3 Comparison of indicative offers of selected factoring companies
Tablica 3. Usporedba osnovnih ponuda pojedinih *factoring* kompanija

Factoring companies *Factoring kompanije*	**Invoiced Limit** *Limit računa*	**Advance** *Pretplata*	**Participation** *Sudjelovanje*	**Interest Rate** *Kamatna stopa*	**Factoring fee** *Trošak factoringa*	**Maturity of receivables** *Rok plaćanja potraživanja*
VÚB Factoring	400 000 €	85 %	15 %	1 M EURIBOR + 2 % p. a.	0.275 %	90 days / dana
ČSOB Factoring	480 000 €	70 %	30 %	1 M EURIBOR + 3 % p. a.	0.352 %	90 days / dana
Factoring SLSP	400 000 €	80 %	20 %	1 M EURIBOR + 2,5 % p. a.	0.485 %	90 days / dana

Nominal value of invoice:	300 000 €
Factoring fee:	0.275 %
Interest rate:	1 M EURIBOR[3] + 2 % p. a (1.22 % + 2 % = 3.22 %)
Maturity of receivables:	90 days
Advance:	85 % of nominal invoice value

Process of financing:

Day 1 – supplier will submit the invoice and send its copy with the delivery note to VÚB Factoring, a .s.

Day 5 – 10 – VÚB Factoring, a. s. will provide the agreed advance to the client:
300 000 € / 100 x 85 % = 255 000 €

Day 91 –purchaser will pay the factoring company 300 000 €
– VÚB Factoring will pay the wood-working company the remaining 45 000 € and will deduct:

a) Factoring fee: 300 000 € / 100 × 0,275	= **825 €**
b) Interest rate for 90 days:(3.22 % × 90 days) / 360	= **0.81 %**
c) Interest expenses for 90 days: 255 000 € / 100 × 0.81 %	= **2 065.50 €**
Total costs:	= **2 890.50 €**

VÚB Factoring a. s. will pay the client: 45 000 € – 2 890.50 € = **42 109.50 €**

The VÚB Factoring, a. s. invoices the wood-working company for the amount of 2 890.50 €, as the cost of factoring, which represents 1.04 % of the total cost of factoring services from the nominal value of the factored claim. The main advantages of financing the claim in question through factoring is in this case the advance of up to 85 % of the claim not later than 10 days from the invoice, and associated with it, the possibility of disposing with these funds (for example for the payment of its obligations or for the purchase and sale of goods to another customer and thereby the increase of the company's income). Another advantage is undoubtedly a protection against possible default risk at the customer site, when the company would have the loss only of 15 % of the claim value.

The main reasons why we recommended the wood-working company in question to use factoring are as follows:
– it eliminates liquidity problems,
– it provides to purchasers a maturity longer than 30 days,
– re-delivery-based commercial contract,
– it eliminates the risk of possible insolvency of the purchaser.

Despite the above mentioned benefits, for most enterprises forfeiting is still not available, mainly because of its high price. Forfeiting can practically be found in the commercial register of all banks as a business activity and even in the register of many small companies with limited liability (Pryl, 1999). However, the definition of forfeiting is not exhaustively defined in the Slovak legislation. Each institution explains it in its own way. The difference between these transactions and transactions between banks and the Central Bank is not quite clear. The banks we contacted only gave us the links to their websites, where forfeiting conditions are indicated very generally. Further to the above, it was not possible to give a statistical overview of the forfeiting market in Slovakia.

3.2 Proposed forfeiting financing for the selected wood-working company
3.2. Prijedlog fortfeiting financiranja u određenoj tvrtki za preradu drva

The analyzed company (the same as for factoring) expanded its business to foreign markets in 2010 and has worked with two Czech customers. An opportunity was offered to the company in 2012, to conclude a commercial contract with a new Czech customer, who showed interest to order products amounting to a total of 100 000 €. The maturity of invoices would be up to 180 days. The company in question had not cooperated with this customer before and had no enough information to verify its credibility. As the company had no experience with the supply with a maturity of 180 days, the management of the company decided to address the bank to verify the possibility of financing the claim by forfeiting

General conditions for the purchase of the claim are as follows:
1. The first condition is that the claim has to be in a stable currency, namely euro – the company must negotiate payment for the supply in euro.
2. The claim must be in the form of a promissory note, which will be guaranteed by the bank of the importer.
3. In the case the claim is very risky for the bank, the bank may require from the company to insure the claim.

The interest rate was set at 15 % per year and the front-end fee at 3 % of the claim.

[3] 1M EURIBOR to 6th May 2011 is 1,22 %

Discount interests = (value of claim × interest rate × number of days) / 36000
Discount interests = (100 000 € × 15 × 180 days) / 36 000 = 7 500 €
Front-end fee = 3 % from 100 000 € = **3 000 €**
Cost of forfeiting = 10 500 €

If the wood-working company in question decided to use forfeiting to finance the outstanding debt, the cost would amount to 10 500 €, meaning that the total cost of forfeiting services are 10.5 % of the nominal value of the claim.

It can be concluded that despite of a relatively high cost for providing forfeiting (compared to other long-term credit forms of financing), the company should consider this form of financing thus ensuring the expansion of its business into foreign markets, be it the Czech Republic or in other cases the possibility of entry into new markets in other countries. The advantage of this form of financing can be seen mainly in removing the risk of possible insolvency of customers, in removing political risks, and of course in the reimbursement of invoice before its maturity. Forfeiting protects the company from insolvency of the customer. The company would not wait for covering this claim on another loan and the main advantage is the possibility to export on loan and to have paid the claim.

4 CONCLUSION
4. ZAKLJUČAK

The conditions under which each company provides factoring and forfeiting services depend primarily on the creditworthiness of the applicant as a customer. For being granted this form of financing, the applicant has to fulfill certain conditions such as: a minimum amount of receivables financed through factoring, a minimum number of purchasers, and others. Despite some disadvantages, such as administrative complexity, fees and interest, and minimum amount of receivables, factoring is a means of funding that should be considered by enterprises in dealing with financial issues. Factoring and forfeiting are the instruments of financing, which can offer businesses a lot, especially with its added value. This method mainly includes protection from insolvency of customers, management of receivables, as well as the opportunity to dispose with the funds before the end of the maturity of receivables. As shown by the example of a company, owing to factoring, instead of 90 days of maturity, the company gets 85 % of the nominal value of invoice in a few days, which helps to avoid insolvency of the company and continue doing business with no financial problems immediately. According to the present case, the company in question has to give up 0.96 % of the nominal value of the invoice to be able to use the financial assets much sooner than a 90 day maturity, which is much less than to be insolvent and jeopardize future business.

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Microtensile Testing of Wood – Overview of Practical Aspects of Methodology

Ispitivanje mikrovlačne čvrstoće drva – pregled praktičnih aspekata metodologije

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ABSTRACT • *Microtensile testing is a specific and delicate variant of standard tensile testing and is performed on small samples. Often also referred to as "thin strip" method, the testing of thin veneers is described in this paper with particular aspects of its field and scope of application, along with comments on reliability and variability of results. Experimental guidelines of the precise technique are presented as well.*
The method consists of preparation of microtomed longitudinal wood sections, which may be treated or exposed to various conditions, agents or weathering, followed by tensile testing in a large number of replicas. Therefore, the reduction in size of samples shortens and/or facilitates the testing. Testing at zero span (the jaws of testing instrument being initially in contact) reflects to a greater extent the mechanical properties of the cellulose component, while the finite (usually 10 mm) span test yields more information about matrix properties i.e. lignin intercellular material and the degree of fibre bonding.
This method has some shortcomings related to the fact that practical applicability is restricted to a small number of species, and that great skill is required to prepare the material, execute the testing and interpret the results. The method may be time consuming and technically demanding, depending on species and type of experiment.
However, further analyses of test strips (like colour measurements, chemical analytical testing, biodeterioration studies, etc.) render the method useful for a multi-aspect approach to specific studies on wood.

Key words: *wood, thin strips, microtensile testing*

SAŽETAK • *Mikrovlačno je ispitivanje varijanta standardnoga vlačnog ispitivanja provedeno na malim probama. Često nazivano „metodom tankih listića“, ispitivanje čvrstoće na vlak mikrotomiranih vrlo tankih furnira u ovom se članku opisuje uz posebno razmatranje polja primjene te metode, kao i uz komentare o pouzdanosti i varijabilnosti rezultata. Članak također donosi eksperimentalne detalje i naputke za provođenje metode visoke preciznosti.*
Prednost te metode očituje se u činjenici da je longitudinalne tanke mikrotomirane odsječke moguće zaštićivati različitim sredstvima (primjerice, impregnirati sredstvima za površinsku zaštitu), potom izlagati različitim utjecajima starenja i, konačno, podvrgnuti ispitivanju čvrstoće na vlak. Male dimenzije individualnih proba omogućuju ispitivanja na velikom uzorku. Ispitivanja na nultome početnom rasponu ispitnih čeljusti uvelike odražavaju mehanička svojstva celuloze, dok ispitivanja na određenom (najčešće 10-milimetarskom) rasponu daju informacije o ukupnim svojstvima materijala – ne samo o svojstvima mikrofibrila nego i o svojstvima veziva (lignina

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i hemiceluloze). Postupci izbora, pripreme, mikrotomiranja, uzorkovanja, izlaganja i ispitivanja opisani u ovom radu ključni su za postizanje pouzdanih rezultata (niskih koeficijenata varijacije), kako pri ponavljanju, tako i pri obnavljanju ispitivanja. Pravilno je mikrotomiranje, pak, ključan korak u procesu pripreme materijala, dok kontrola debljine osigurava kvalitetu pripremljenog materijala, a time i pouzdane i točne rezultate.

Nedostatak opisane metode jest to što je praktična primjenjivost smanjena na mali broj vrsta drva. Nadalje, metoda zahtijeva veliku vještinu i pozornost operatera pri pripremi materijala, provođenju ispitivanja i interpretaciji rezultata. Metoda je tehnički zahtjevna, a pokusi mogu biti dugotrajni. Unatoč tome, primjena te metode omogućuje relativno brz i pouzdan način ocjene kemijskih i strukturnih promjena, ispitivanja biološke razgradnje i drugih promjena tankih slojeva drva.

Ključne riječi: *drvo, tanki listići, mikrovlačno ispitivanje*

1 INTRODUCTION
1. UVOD

Cellulose, forming the skeleton of the essential structural units of wood - microfibrils - is itself extremely strong in tension because of the covalent bonding within the pyranose ring and between individual units. Hydrogen bonds within the cellulose crystalline and para-crystalline regions provide rigidity to the chain via stress transfer and allow the molecule to absorb shock by subsequently breaking and reforming when longitudinally stressed in tension. The hemicelluloses are found in the amorphous regions of the cellulose chains, particularly in peripheral wall layers of the wood cell, and are regarded as the connecting material between cellulose and lignin. Lignin itself is considered to be the adhesive of the cellulosic units and the bulking and rigidising material in respect to the structural cellulosic units. Following this, it is easy to understand that any chemical changes of wood constituents will weaken either the lateral bonds and affect the stress transfer, or the cellulosic units themselves. The mechanical parameter that reflects most sensitively these changes is tensile strength parallel to the grain (Ifju, 1964; Evans and Banks, 1990; Derbyshire and Miller, 1981; Derbyshire *et al*., 1996). It was demonstrated by numerous experiments that the tensile strength may precisely reflect the chemical changes of wood constituents due to exposure to biodegradation, acid conditions or weathering (Razckowski, 1980; Derbyshire and Miller, 1981; Evans and Banks, 1985; Evans *et al.,* 1992a; Evans *et al*., 1992b; Lehringer *et al.,* 2011). In order to record the fine changes, which are restricted either to a shallow surface layer or their distribution in depth of the sample, the microtensile testing technique can be successfully applied to various kinds of modification processes (Jirouš Rajković *et al*., 2004; Turkulin *et al*., 2006, Xie *et al*., 2007).

On the ultrastructural level, the densely packed secondary layers of the cell wall (esp. the S2 layer) are the strongest portions of the softwood tracheid. Those tubular cells, usually ca 3 mm (in spruce and pine) or 4.6 mm long (in western red cedar), are bonded to adjacent cells by the lignin rich middle lamella (or "compound middle lamella", CML, if the loose primary wall is understood to be a part of this bonding layer). Since the jaw separation of conventional testers is much greater than the microfibril length or the fibre length, the standardised tensile tests measured the combined mechanical properties of the microfibrils and matrix. It is of interest, therefore, to distinguish between the microfibril strength, or essential fibre strength, and the overall strength, where the inter-fibre bonding, especially in the CML region, plays a significant role. Attempts were made to separate the tensile properties of the cellulosic material from the intercellular material by determining wet strength values of the thin strips so that the CML would be excessively plasticised by water (Derbyshire and Miller, 1981; Evans *et al*., 1992b). Nevertheless, it proved necessary to carry out the investigations by means of tests in which the initial separation of the jaws could be set to a span less than the average length of cellulose microfibrils.

Microtensile testing is a specific and delicate variant of standard tensile testing and is performed on small samples. Often also referred to as "thin strip" method, the testing of thin microtomed veneers, described in this paper, monitors the surface changes and reactions (e.g. due to weathering), where the microtensile specimen represents a shallow surface layer.

Reduction in the size of tensile samples to microtensile samples, usually having thickness less than 100 μm, is a useful technique when a fine anatomical distribution of wood properties (e.g. variations in chemical, mechanical and physical properties within a growth ring) is investigated, or when strength properties should be determined on material without great structural flaws.

2 MICROTENSILE TESTING
2. MIKROVLAČNA ISPITIVANJA

2.1 General description
2.1. Opći opis

There are two variants of the microtensile testing technique. The zero span test is a test in which the jaws or clamps are initially in contact. When this test is applied to wood strips, virtually all the microfibrils in the cross section bridge the gap between the clamps so that the test is principally a measure of microfibril strength. Since the microfibrils are the high-strength component of wood structure, the zero span tensile strength is greater than any value of tensile strength determined in a finite span test. It reflects to a greater extent the mechanical properties of the cellulose component, while the finite span test yields information about matrix properties i.e. lignin/hemicellulosic intercellular material and the degree of fibre bonding.

The main advantages of the method compared to conventional mechanical techniques are small sizes of samples that allow the preparation of a great number of defect-free specimens from a limited source of material. The large surface-to-volume ratio of samples allows a uniform application of chemical and physical treatments throughout the cross section of the pieces. Finally, the ensuing failures can be microscopically studied on a cellular level. The large number of replicates meets the requirements of the statistical processing of data (Kennedy and Ifju, 1962; Derbyshire *et al*., 1996).

Short span tensile testing technique was originally developed for testing paper. The span must be shorter than the length of single fibres in a paper sheet. Testing at various short spans yields valuable information about the fibre strength, average fibre length, inter-fibre bonding and the general fibre quality in the paper sheet (Pulmac, 1992). Paper testers have been applied in wood science as a variant of microtensile testing (detailed review presented by Turkulin, 1996). The first attempt of using microtensile testing in wood research was to determine the influence of variations in ring orientation and anatomy on tension and compression failure of match-stick size bending specimens. The main conclusion of that study was that the specimens "should be of small dimensions so that anatomical differences might be large in comparison with overall dimensional values" (Forsaith, 1933). The method was also successfully applied for the analysis of differences in the density, compression, tension and bending strength of latewood and earlywood of softwoods (Ylinen, 1942). Microtensile technique was further applied in studying the effects of silvicultural treatments on the structural properties of wood that also led towards the idea of analyzing the within-ring variations in the density and mechanical properties of conifers from pith to bark (Kloot, 1952). Testing of successive rings of several conifers revealed that the tensile strength is greatly influenced by the orientation of the microfibrils in the S2 layer and that the reduction in the angle of microfibrils to the cell axis is closely linked to the increase in tracheid length, density, cellulose content and tensile strength (Wardrop, 1951). Wet and dry testing led Wardrop towards raising the important issue of the effect of water on the failure mode and to the speculations about the different influence of moisture on lignin bonding ability and the strength of the micelle structure.

Tracheid length and cellulose content are consistently correlated with the tensile strength, but the fibril angle is also a significant (inversely correlated) variable for latewood strength (Ifju and Kennedy, 1962). Authors noted that earlywood and latewood exhibit different types of failure since latewood has an indicated strength 3.2 times greater than that of earlywood, yet has only 1.8 times as much cell wall substance (Figure 1). The enhanced ability of individual cells of latewood to resist stresses may be attributed to the presence of a greater proportion of highly oriented secondary wall material.

Tensile properties are highly associated with specific gravity and wet ultimate tensile strength corresponds well with modulus of elasticity (r=0.98) (Ifju *et al*., 1965a; Wellwood *et al*., 1965). Wet tensile strength reflects very fine differences in ultramicroscopic architecture of the cell walls (Kennedy, 1966) as well as the variations in physical and mechanical intra-increment wood properties (Ifju, 1969). Specific gravity and wet tensile strength may exhibit a 4-fold increase from earlywood to latewood in conifers. Modulus of elasticity of wood samples correlates well with the dry tensile (finite span) strength going from earlywood to latewood in the growth ring (Nordman and Quickström, 1969). Ifju *et al*. (1965a) came to the same conclusion for wet testing.

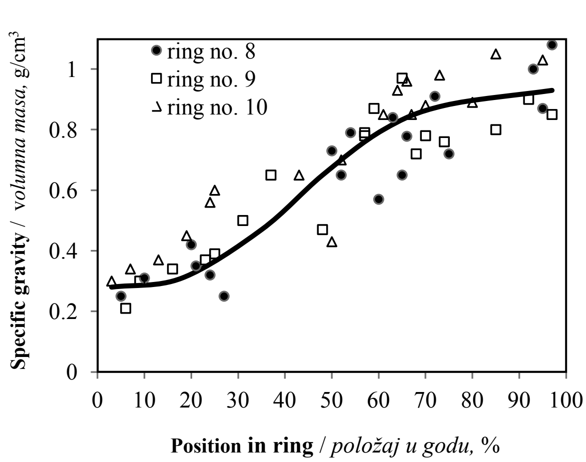

Figure 1 Variation in specific gravity of wood in three adjacent increments in loblolly pine (*Pinus Taeda* L.) (Ifju and Kennedy, 1962).
Slika 1. Varijacije volumne mase drva triju susjednih godova borovine (*Pinus Taeda* L.) (Ifju and Kennedy, 1962)

Mark (1965, 1967) developed a radially cut sample, which consisted of only one complete row of tracheids (25 μm thick), 8 to 10 cells (200 μm) in width, and was free of rays in its constricted neck area. He determined the minute stress and strain values, microfibrils angles and proportion of particular cell wall layer in the net cross-sectional area, chemical composition and packing density distribution within the cell wall. Based on such analysis, the tensile properties can be associated with chemical wood constituents, their proportions and organization (distribution in the layers, proportions of layers in the net cross-sectional area, microfibril angle and the bond between microfibrils etc.). It forms a basis for the interpretation of the failure mode i.e. anticipates the intention that the fractographic evidence reveals the chemical decomposition of the cell wall (Turkulin and Sell, 2002).

Problems that greatly influence the results of the micro-tensile strength measurements are the variations in specimen geometry (particularly uniformity of thickness), angle of grain, density, structural characteristics, etc. (Biblis, 1969). This author stressed that the wet strength of 100 μm thick samples is on average 50 % lower than the strength of green standard samples, or of the samples containing entirely earlywood or latewood zones. He attributed those differences to either microtoming damage or to the occurrence of longitudinally and/or obliquely cut cells on either side of microspecimen, which causes irregular distribution of combined stresses, rather than uniform longitudinal tension. This conclusion is important, since some authors (Forsaith, 1933; Kloot, 1952) believed that the strength of microspecimens, because of the minimization of the inherent flaws, should be greater than that of standard samples. The effect he noticed is however much more evident in wet than in dry testing, as the water plasticises the middle lamella to a greater extent than the cell walls. The relative influence of the middle lamella strength on the overall strength increases with the reduction in thickness. Regardless of the possible microtoming damage, there is a high degree of association between tensile properties and thickness of microtomed sections up to 200 μm thickness (Biblis, 1970). This is a good confirmation of Mark's analysis (Mark 1965, 1967) of the influence of the proportion of the sliced cells in the cross section on the reduction in overall strength.

2.2 Assessment of photodegradation by application of microtensile testing
2.2. Ocjena fotodegradacije primjenom mikrovlačne tehnike

Microtomed wood sections can also be applied in monitoring photodegradation (Kalnins, 1966; Raczkowski, 1980; Derbyshire and Miller, 1981). Most recent comprehensive work in that area may be found in the thesis of Živković (2011). Raczkowski (1980) assessed the surface „corrosion“ based on the long range tensile testing of 100 μm thick spruce (Picea abies, L.) strips to evaluate the combined effects of sunlight and atmospheric pollutants. Derbyshire and Miller (1981) additionally observed fungal colonization, which was negligible in dry and sunny periods, but very intensive in late autumn and winter. They also tested the influence of different spectral regions of solar radiation on the photodegradation rates. Thin strips were used for tensile strength testing in both dry and wet conditions, modulus determination, SEM fractographic analysis and determination of the cellulose disperse viscosity. Their main conclusion was that the tensile measurements on weathered strips yield a more accurate and relevant assessment of weathering damage than observations of colour change and the breakdown of microstructure. They were able to distinguish between the initial lignin breakdown and more profound effects of the depolymerization of the cellulose constituent, the latter being monitored by strength changes over zero span and by cellulose disperse viscosity changes. Additional evidence to explain the weathering process was found in microscopic analysis, but the structural changes, especially in the early weathering phases, did not prove such a sensitive parameter as the tensile strength loss. Turkulin later showed (Derbyshire *et al.*, 1996; Turkulin and Sell, 2002) that microscopic evidence can essentially corroborate the complete comprehension of the failure origin and mode.

The thin strip technique has been extensively applied by other researchers in studies of the degradation of exposed wood surfaces. Evans and Banks (1985, 1988) successfully examined the effects of hot water on wood degradation, and the effect of dilute acids (Evans and Banks, 1985). Testing in wet and dry conditions enabled speculations about the nature of the failure, i.e. the influence of water on the inter-fibre bonding and on the microfibrilar bonding. Derbyshire and Miller (1981) and Evans and Banks (1990) came to the same conclusions that the chemical and ultrastructural changes accord with the losses in tensile strength of thin strips and that the failure mode can reveal the nature of chemical decomposition of wood constituents.

Evans *et al.* (1992a, 1992b) showed that finite span testing reveals delignification more rapidly than zero span testing. This was further confirmed by chemical analysis of the lignin content and by FTIR spectral analysis performed on weathered strips and subsequent SEM analysis which contributes to the explanation of the effect of chemical changes to the structural integrity and consequent strength characteristics.

Derbyshire and Miller also continued their work on weathering using extensively the thin strip method. They investigated the effect of temperature (Derbyshire *et al.*, 1997) on photodegradation rates and applied the method to the assessment of photostabilisers of wood. They also evaluated artificial weathering devices and demonstrated that they offer a consistent, reliable and precise means of determining photodegradation rates for wood (Derbyshire *et al.*, 1995, 1996). The strength changes were shown to be consistent with fractographic evidence of the structural changes in wood, namely with cell delamination, development of brittleness and loss in cell wall integrity (Turkulin and Sell, 2002). Thin strip technique was also used to investigate the effect of moisture on photodegradation rates (Turkulin *et al.*, 2004), which proved to be a significant factor in accelerating photodegradation of wood by increasing the rates of strength loss.

Jirouš Rajković *et al.* (2004) and Turkulin *et al.* (2006) sucessfuly applied the thin strip method to test the effectiveness of several surface treatments, as well as to monitor the depth profile of photodegradation. Radial, but also pure tangential earlywood strips of softwood, were assembled in packs of three. The first strip in the pack was either surface treated or covered with free film of clear stain. The strips reflected very sensitively the effects of photodegradation and gave valuable information on the effectiveness of tested protective materials.

3 DESCRIPTION OF THE METHOD
3. OPIS METODE

3.1 Material selection for preparation of radial strips
3.1. Izbor i priprema materijala za radijalne listiće

If strips are to be microtomed from the radial surfaces of small wood blocks (radial strips), rectangular wood blocks should be straight grained, free from all visible defects, machined and smooth planed. Additionally, to ensure more uniform stress distribution between the latewood bands and within the whole strip, test specimens should be prepared with the same number of latewood bands having earlywood zones at their edges (Figure 2). Since the stress during microtensile testing is much greater in latewood than in earlywood, strips with latewood band at their edges would determine the point of ultimate stress and affect the result (Kufner, 1963; Turkulin and Sell, 2002). Typical material based on density, ring width and latewood portion consists of 4 to 5 rings per 10 mm width. Optimal dimensions of the block for microtoming are 100 mm in length, 40 mm in height and 10 mm in thickness. Properly microtomed block of 40 mm width yields about 300 strips of nominal thickness of 80 μm. To obtain a sufficient number of strips for a series of trials, it is often necessary to section more than one block. Blocks that are adjacent in longitudinal direction (prepared from the same stick) are favoured in order to avoid the differences in density, number and the overall width of the annual rings and inclusion of uneven proportions of the latewood that could influence the results (Figure 3). Reliability of a test may be enhanced by assembling batches of strips from a mix of all the blocks using the same pattern of selection (e.g. 2 + 2 + 1 from three blocks, or 1 strip from each of five blocks).

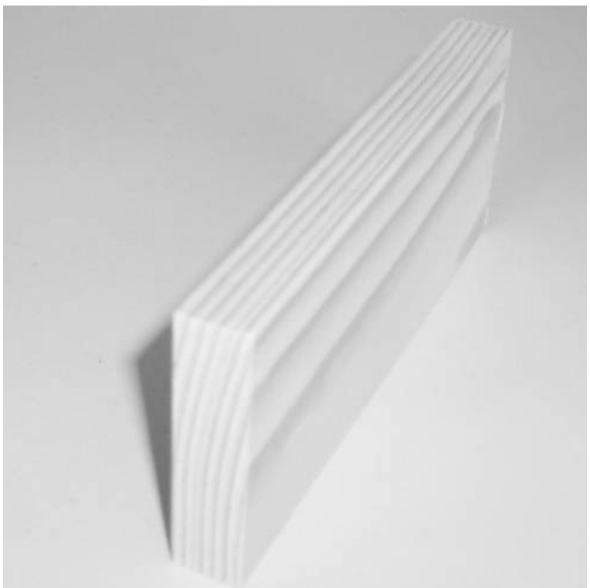

Figure 2 Fir wood block for production of radial strips
Slika 2. Blok jelovine za izradu radijalnih listića

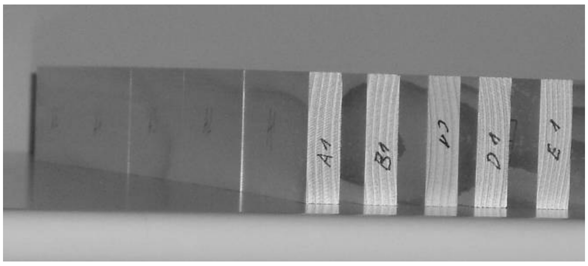

Figure 3 End-grain scans of fir wood blocks prepared from five sticks (letter mark on the block denotes the stick, number mark denotes a position within the stick)
Slika 3. Blokovi jelovine pripremljeni od pet štapića (slovo na bloku označava štapić, a broj označava položaj unutar štapića)

3.2 Preparation for microtoming
3.2. Priprema za mikrotomiranje

Prior to microtoming, the blocks are plasticised by means of waterlogging. The procedure (described in detail by Turkulin, 1996) is conducted in a vessel where blocks are vertically positioned, separated with Perspex spacer bars so that all the surfaces are exposed to water, loaded with lead weights to prevent their floating and waterlogged until full saturation using vacuum under ambient temperature. Desiccator is evacuated for at least 30 minutes, after which the water is gradually infused without releasing the vacuum until the blocks are fully immersed. The vacuum is maintained for the next 2 – 4 hours, after which the ambient pressure is restored by admitting the air into the vessel and leaving the blocks soaking over night. Afterwards the blocks are exposed to several changes of vacuum of 4 – 5 mm Hg and atmospheric pressure in the 10 – 15 % solution of ethanol until no air bubbles appear on the surfaces of the blocks after re-establishing the vacuum. For permeable species, soaking overnight is usually ample time to achieve full penetration of the blocks, whereas for impermeable species (like Pine heartwood, Western red cedar or Norway spruce) the vacuuming in water usually needs to be repeated for the next several days. When completely saturated, blocks normally show no tendency to float. Blocks are kept fully immersed until required for sectioning, but not for longer than 10 days. The water should be changed occasionally and fresh ethanol added to prevent developing any mould or bacterial growth.

3.3 Microtoming
3.3. Mikrotomiranje

The strips may be microtomed with a conventional sliding microtome, using either conventional knives or knives with exchangeable blades. The most important factors of good microtoming quality are the condition (sharpness) of the blade (Turkulin, 1996), cutting angle (Dinwoodie, 1966; Keith and Côté, 1968; Kennedy and Chan, 1970; Turkulin, 1996), vibrations (Wachtel *et al.*, 1966) and condition of microtomed surface. Bluntness of the cutting edge, which is the most influencing parameter for the quality of cutting, causes compression of the wood underneath it (mainly on the latewood bands) and results in warped strips.

This is very significant for the thin strip method since the tensile strength is mainly determined by properties of the latewood. The best slicing results on softwoods are obtained when the inclination angle of the knife is 16° (tilt angle on the microtome scale), the draw angle (the angle between the blade and the grain of wood) is 22° and polishing angle of the blade 18°. Smaller inclination angles cause the blade to compress the wood that forms the next strip, while angle greater than 18° yields coarser strips. Vibrations during microtoming, caused by improper or loose block mounting, usually cause nonuniform thickness of the strips and result in faster blunting of the knife. Condition of the blade can also be tested by occasional attempts to cut only 10 to 15 μm thick strips. If such strips were inconsistent or not complete over the whole surface, the blade should be exchanged. To enable successful microtoming, the surface should be continuously lubricated with a mixture of 10 % ethanol in distilled water by maintaining the film of liquid on the cutting surface.

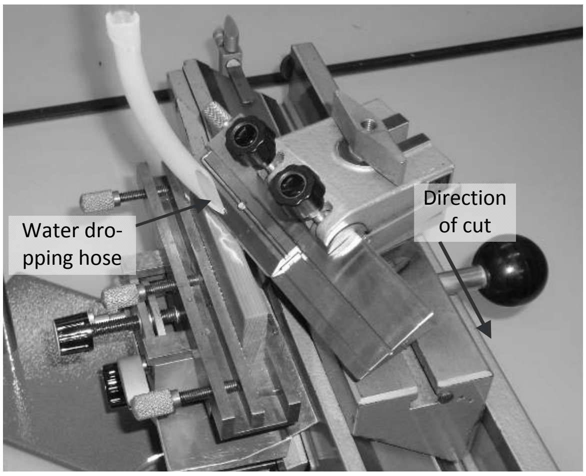

Figure 4 Appearance of the knife with exchangeable blades and the principle of lubricating wood surface during microtoming
Slika 4. Prikaz noža s izmjenjivim oštricama i načina močenja proba tijekom mikrotomiranja

Optimal thickness of the radial strips is around 80 μm for it is proved to yield the optimum strength values when Pulmac paper testing instruments are used. The softwood strips of such thickness usually consist of two rows of tracheids, of which at least one would be complete. Strips thicker than 90 μm cause ultimate loads to failure that fall out of the range where the rate of loading on Pulmac paper testers is constant, and may cause slippage from the clamps of standard tensile machines equipped with micro-tensile unit. Latter cases render the results which are unreliable, while testing of strips thinner than 60 μm generally causes great variability of the results.

3.4 Preparation of tangential strips
3.4. Priprema tangentnih listića

Due to uneven distribution of physical properties within the softwood ring and practical problems of microtoming, it is not possible to use or accept all the strips microtomed from earlywood or latewood portion within a single annual ring. Therefore, only the strips are selected that represent the relevant incremental zones within the tree ring. While the density of the late wood is almost constant, the early wood density is low at the initiation of the ring, then constant only up to ca 40 % of the growth ring, after which it increases up to several times (Ifju *et al*., 1965b; Kennedy, 1966; Ifju, 1969; Wellwood *et al*., 1965). Greater problems occur with species with gradual ring transition than with species with abrupt transition from earlywood to latewood. Practical microtoming problems may be manifested as non-uniform properties over their entire length of the strip and the increased number of strips required for replication.

In order to get strips with as uniform initial properties as possible, that may later give reliable results, earlywood strips can be taken from the zone with position of approximately 5 to 40 % in the ring width, and latewood strips from the position of 75 to 95 % within the ring (Turkulin, 1996; Jirouš Rajković *et al*., 2004). This also means that small ring widths further aggravate the microtoming process and reduce the number of usable strips. Contrary to microtoming radial strips, blocks for tangential strips should be machined with cutting plane as parallel as possible to the tangent to the ring boundary, since any misalignment requires additional sections prior to obtaining uniform strips. Preparation of strips containing only earlywood is easier and more efficient if the blocks have wide annual rings. The use of pure earlywood material can be justified by the fact that the earlywood is much more prone to weathering and that the effects of modifications on improvement of surface properties could then be successfully performed solely on earlywood strips.

3.5 Thickness measurements and variability
3.5. Mjerenje debljine i njezina varijabilnost

Proper microtoming is a crucial point in preparation procedure in thin strip method, ensuring low variability of results. Furthermore, uniform and even thickness of the strips reflects the quality of the testing material and guarantees reliable and accurate tensile testing results.

After natural drying, thickness of the strips is checked on all strips in order to avoid undesirable aberrations of tensile strength within and between the batches of strips. Strips that do not fit into a certain thickness range are discarded and selected material is additionally checked for thickness in order to define the concordance of the strip thickness with the nominal value. This is important as it enables comparisons of the material from different blocks.

The thickness is usually measured with electronic thickness gauge having a semi-spherical tip and the accuracy ± 0.1 μm. Measurements are taken every 2 cm along the strip or along the entire strip length. To avoid incorrect readings due to excessive pressure of the gauge tip to wood strips (that could cause deformations, especially on earlywood bands), the gauge should exert minimum available force on the tip. All the strips that do not fall into the range of ± 5 % shall be rejected. However, provided that the sectioning is performed correctly, not more than 10 % of radial strips having nominal thickness of 80 μm fall out of the range of ±3μm, whereas tangential earlywood strips vary even less (only ± 2 μm) (Turkulin, 1996).

4 Application of the Pulmac short span paper tester
4. Primjena Pulmac kidalice

The Pulmac machine is operated pneumatically using compressed air to provide both the load and the clamping pressure of the jaws. The basic machine offers the facility to carry out tests at initial spans in the range 0 to 1.6 mm. When adapted, long range tensile tests at 10 mm initial span can also be carried out. The Pulmac tester can be additionally equipped with a transducer, which allows the recording of strain, i.e. determination of the modulus of elasticity.

Particular advantages of the use of Pulmac testers are:
- ability to control the clamping pressure
- precise alignment of the sample in the clamps, parallel to the load direction
- low risk of damaging the samples by clamping (virtually no failure at the clamps in finite span testing)
- considerable savings in time during tensile testing.

The main value representing tensile properties is the ultimate breaking load in tension parallel to the fibres. This approach is advantageous compared to calculation of tensile stress because of problems in defining the cross-sectional area of a cellular material and of determining the changes of a cell wall thickness after degradation. Reduction in the cross-sectional area may arise either due to weathering or as a consequence of chemical or biological degradation. The same net cell wall area can be represented by different formation of cells (e.g. two rows of complete cells are much stronger than one row of complete cells lined by two rows of half-split cells). Furthermore, weathering will cause much greater strength loss than the reduction of the cross-sectional area. For this reason, instead of recording absolute tensile stress strength values, it is very often more convenient and interesting to express the results as relative changes (be it retained strength or relative strength loss).

Two main variables in the operation of the Pulmac testers are the rate of loading and the clamping pressure of the jaws. To achieve an accurate value of the tensile strength of the sample, it is essential to achieve the clamping pressure of the jaws high enough to prevent the slippage of the sample whilst not being so high as to cause physical damage to the delicate sample. Too low or too high a clamping pressure would result in a measured failure load lower than the true failure load (Figure 2).

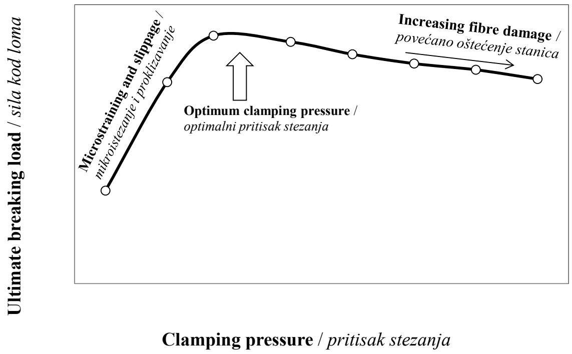

Figure 5 Influence of clamping pressure on the ultimate breaking load (Pulmac, 1992)
Slika 5. Utjecaj pritiska stezanja na najveću silu loma (Pulmac, 1992)

In 10 mm span testing the choice of clamping pressure is relatively straightforward and less critical than in 0 mm span testing. Too high a clamping pressure will cause the failure in the jaw or in the part of the strip immediately adjacent to the edge of the jaw. Such failure appears as a straight line, possibly with small “teeth” on it, across all or a part of the width of the strip. Too low clamping pressure results in slippage of the whole strip under one jaw, or slippage of portions of the strip under the jaws before the moment of failure. It is therefore recommended to perform preliminary testing at lower pressures, and increase the pressure until no slippage occurs and the failure spreads in the middle portion of the strip, or across the area between the jaws. This will completely eliminate the risk of failure at the grips - which was a great concern of several authors (Ifju *et al*., 1965a; Michon *et al*., 1994). Should the ray appear across the body of the sample, thus presenting the discontinuation of axial, tension-loaded cells, the failure spreads across the border between the ray cells and tracheids. The load to failure is regularly much below the average for the batch, and such samples should be discarded. The inclusion of longer ray cells in the loaded area should be avoided by microtoming the strips at certain small angle to the radial plane (usually 3 – 5°). Further care should provide that the ray lines are excluded from the loaded areas during sectioning of the strip into testing samples.

In 0 mm span testing, the failure occurs in the very narrow area in between the jaws, and within the fibres under the edge of the jaws. It is therefore impossible to apply the “failure-at-the-grips” criterion described in 10 mm span testing. The optimum setting of clamping pressure is associated with the maximum load to failure that is determined by carrying out several preliminary tests at different pressures, additionally confirmed by visual checks on the fractured sample. A proper zero span failure should result in the failed edge being a straight line with up to approximately 0.5 mm long “teeth” on it. Very “clean” failure indicates too high a clamping pressure, whereas longer teeth, often triangle-shaped, occur generally at too low a clamping pressure, when the portions of the strip had been pulled out under the whole clamp stop.

The appearance of finely jagged failure line is caused by so called "residual span", indicating that some fibrils were not clamped by both jaws. In that case, the span is not zero but a small finite span with increased role of interferer bonding and reduced ultimate load. Consequently, the difference between zero and finite span values is reduced. Microscopic examination during preliminary testing may reveal whether the adequate mode of failure was obtained, without excessive damage to the sample (Figure 6).

One should take into account that clamping pressure during the test should be adjusted to changes in tensile strength. As material becomes weaker or more brittle with prolonged exposure, the same clamping pressure will cause ever greater damage to the delicate specimens and, consequently, higher rates of strength loss with time.

A characteristic type of failure occurs sometimes in the initial strength determination described as "combed" failure (Figure 7). Due to the differences in compressibility of earlywood and latewood regions, or differences in thickness of those portions due to improper microtoming, the earlywood bands are not firmly gripped by the jaws. The failure in the stressed zone occurs in latewood portions, while the earlywood portions are separated along the ring border and transition zones and slip through the jaws. This behaviour has been noted previously by Law and Koran (1979). Where possible, all the strips from the block with described anomaly should be discarded. However, the occurrence of this failure mode need not necessarily mean that the initial testing results are invalid: the strength of the strips is in any case predominantly determined by the strength of the latewood bands, and as the failure and slippage of earlywood does not occur before the failure of the latewood portions, it is likely that the earlywood fibres bear the load and contribute to the stress distribution. Their failure and slippage occur after the ultimate load to failure has been reached, and are associated with the crack propagation phase. The strength of such strips, indeed, was not noted to be lower than is the strength of strips with "normal" failure (Turkulin, 1996).

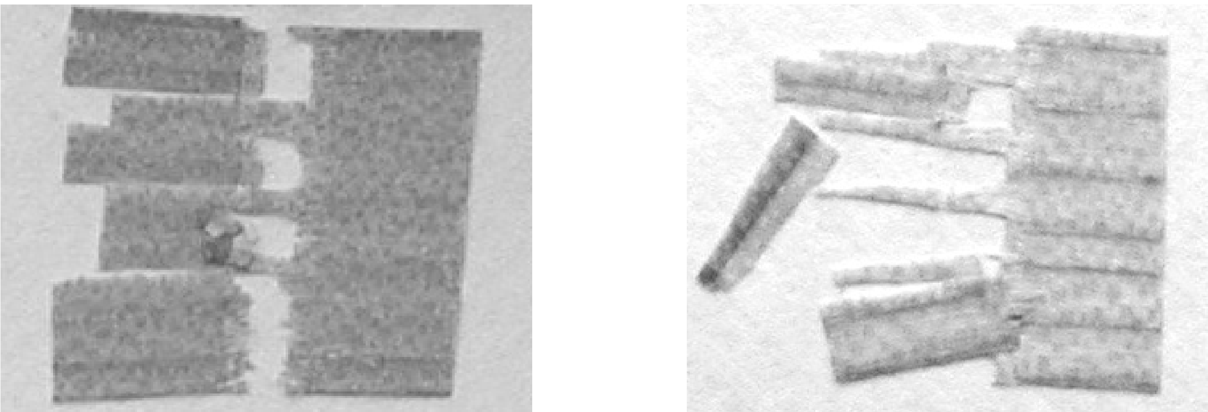

Figure 6 Schematic presentation of a "combed" failure in zero span testing due to different compressibility of early wood and late wood bands
Slika 6. Shematski prikaz "češljastog" loma pri ispitivanju na nultom rasponu zbog različite stlačivosti pruga zona ranoga i kasnog drva

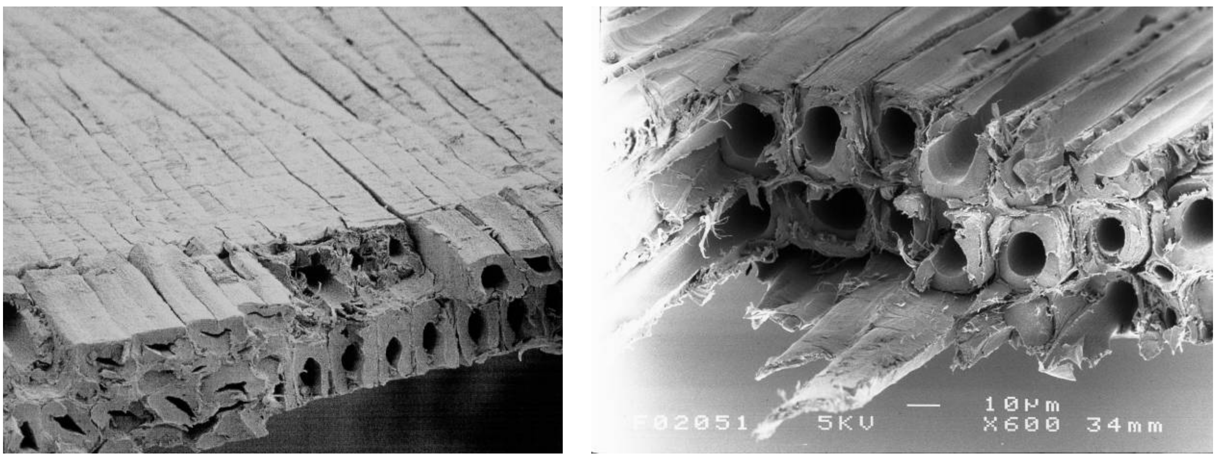

Figure 7 Latewood bands after tensile testing at zero span of clamps. Left image shows the damage and compression of wood tissue imposed by the clamp stop. Right image depicts regular failure mode.

Slika 7. Pruge kasnog drva nakon vlačnog ispitivanja na nultom rasponu hvataljki. Lijevo se vidi da je stopica čeljusti ispitnog stroja zgnječila i oštetila vlakanca, što uzrokuje lom pri manjim vlačnim silama. Desno je pravilan lom bez oštećenja staničja.

Careful preparation, microtoming, selection, batching, exposing and testing procedures as described here, enable to attain sufficient precision of the method and acceptably low coefficients of variation (Derbyshire et al. 1995). The 10 mm span test is more affected by unpredictable factors such as micro-flaws in the strips and the speed and path of crack propagation; therefore coefficients of variation of up to 19 % can be expected in untreated material. Where possible, material should be chosen with an initial strength coefficient of variation not much higher than 10 %. Coefficients of variation for degraded material are usually higher and increase with exposure time.

Variability of the strips is highly influenced by general macroscopic physical properties (Table 1). Since these properties can differ significantly even between blocks taken from the adjacent positions in the stem or in the board, they should be carefully checked. Another, particularly important factor is the microfibril angle in S2 layer (its significance is best presented in comprehensive work by Mark, 1967) and variations between intra-increment densities (as shown by Ifju, 1969, or Wellwood *et al*., 1965). These properties are not easily measured, but the choice of blocks and their mutual position (relevant to the cambium initial, or to the position in the board) may assure the uniformity of essential physical properties of the material. Therefore, great care must be taken if comparison is being made between the results of trials performed on material from different groups of blocks.

Table 1 Factors causing irregularities of the results
Tablica 1. Čimbenici nepravilnosti rezultata

<table>
<tr><td colspan="5">1) Variability of strips tested / Varijabilnost ispitnih listića</td></tr>
<tr><td>a) choice of material / izbor materijala
- density / gustoća
- ring width / širina goda
- latewood proportion / udio kasnog drva
- width, height, number and distribution of rays / širina, visina, broj i raspored trakova
- latewood density and difference between early-wood and latewood densities / gustoća kasnog drva i razlika između gustoće ranoga i kasnog drva
- microfibril angle (particularly in latewood) / kut uspona mikrofobrila (pogotovo u kasnom drvu)</td><td>b) material preparation process / tijek pripreme materijala
- drying stresses and defects / naprezanja i oštećenja tijekom sušenja
- saturation procedure / postupak impregnacije</td><td>c) structure of strips / struktura listića
- number of rings, position of latewood bands / broj godova i položaj zona kasnog drva
- angle of cutting (grain angle) - amount and variation / kut rezanja (otklon žice) - njegov iznos i odstupanja
- lateral angle (between ring boundary and cutting plane)
- amount and variation / pobočni kut (između granice goda i ravnine rezanja) - njegov iznos i varijacije
- position of tangential strips within tree ring / položaj tangentnog listića unutar goda</td><td>d) microtoming errors - slip lines & delamination / greške mikrotomiranja - linije nagnječenja i delaminacija</td><td>e) thickness of strips / debljina listića</td></tr>
<tr><td colspan="5">2) Variations in exposure conditions (for weathered material) / Varijacije u uvjetima izlaganja (za izlagani materijal)</td></tr>
<tr><td>a) radiation dose received / primljena doza zračenja</td><td colspan="2">b) moisture conditions during exposure / uvjeti vlažnosti tijekom izlaganja</td><td colspan="2">c) temperature during exposure / temperatura tijekom izlaganja</td></tr>
<tr><td colspan="5">3) Tensile testing parameters / Patametri ispitivanja vlačne čvrstoće</td></tr>
<tr><td>a) loading rate / brzina opterećenja</td><td>b) clamping pressure / pritisak hvatanja</td><td>c) climate conditions during testing / klimatski uvjeti tijekom ispitivanja</td><td>d) mechanical damage due to handling / mehanička oštećenja pri rukovanju</td><td>e) exposure to light during storage prior to testing / izlaganje svjetlosti tijekom pohrane prije ispitivanja</td></tr>
</table>

The differences between the strips from different sets of blocks could be caused by drying stresses and the collapse. However, this is generally avoided by the choice of blocks from either naturally seasoned commercial stock or from the freshly fallen tree.

Saturation procedure can cause irreversible changes of the material. There are indications in the literature that the hydrolytic processes in wood are actually very slow at room temperature (Evans and Banks 1988, 1990) but one should not neglect the possibility that the longer storage in water may cause some degradation of the blocks. Similarly, the amount of ethanol in water and the level of vacuum applied to the blocks may result in differences in swelling and the migration of the resin to the surface, which was observed during the work done by Turkulin (1996).

Provided that the choice of blocks (the grain angle) and the thickness measurements are performed correctly and results show no great aberrations, the strips should not exhibit structural differences that could significantly reduce the strength. The ray effect or incorrect angle to the radial plane are manifested on individual readings, whereas the grain angle influences the strength of the whole material from one block and is manifested in every batch. In this case the differences between zero and 10 mm span strength are smaller than usual, the coefficients of variation are greater than usual and this is valid for all the batches in the trial.

The effect of temperature on weathering rates (Derbyshire *et al.*, 1996) is estimated to be much smaller than the effect of light and moisture, and the relative effect of up to 5 % temperature oscillations was empirically shown to be practically negligible (Turkulin, 1996).

The radiation dose and exposure humidity are very influential factors and should be carefully maintained at the desired and constant level during artificial exposures of the strips. Fluorescent lamps exhibit significant differences in the irradiation output along their length, therefore an exposure pattern of rotation and replacement of strip holders should be devised that enables uniform and equal level of radiation dose for all samples in the chamber. A single batch showing significantly lower or greater strength in both zero and 10 mm span usually indicates the difference in the incident irradiation dose.

Humidity fluctuations during exposure, particularly the presence of liquid water (condensation) may severely affect the degradation of affected material (Figure 8).

The relative humidity of air during exposure and testing is, along with the clamping pressure, probably the most influential factor on testing results and was shown to cause great strength deviations in both zero and 10 mm span (Turkulin, 1996).

If some strips significantly vary in their physical properties or thickness within the batch, usually only one or two strips show the excessive strength values. Minimum or maximum values for this particular batch exceed by far the usual range. If one block differs from the other two in any characteristics, again 2 or 4 readings in successive batches show excessive strength values. Subsequent examination of the strips yielding unusual strength generally gives answers as to the reasons for irregularities (see micrographs in Figure 7); most often the causes lay in thickness, angle of cutting (ray appearance) and latewood portion aberrations.

5 CONCLUSIONS
5. ZAKLJUČAK

The microtensile "thin strip" method is a useful and reliable means for the determination of relative mechanical properties on small clear samples, but also the changes induced in wood tissue due to chemical modification, weathering or biological deterioration. However, the method is delicate, may be time-consuming and requires specific skills and instrumentation. Testig material should be chosen very carefully to prevent the intrinsic variabilities of wood to obscure the variable under test. Accuracy and reproducibility of the results greatly depend on preparation procedure, selection of material or number of samples, density, thickness, thickness variability, moisture content and temperature during testing as well as the rate of loading. A strict control of the parameters listed in this paper will improve the accuracy and reliability of results. Nonetheless, having all influential parameters under control, the thin strip method provides excellent scientific tool for various tests of wood properties.

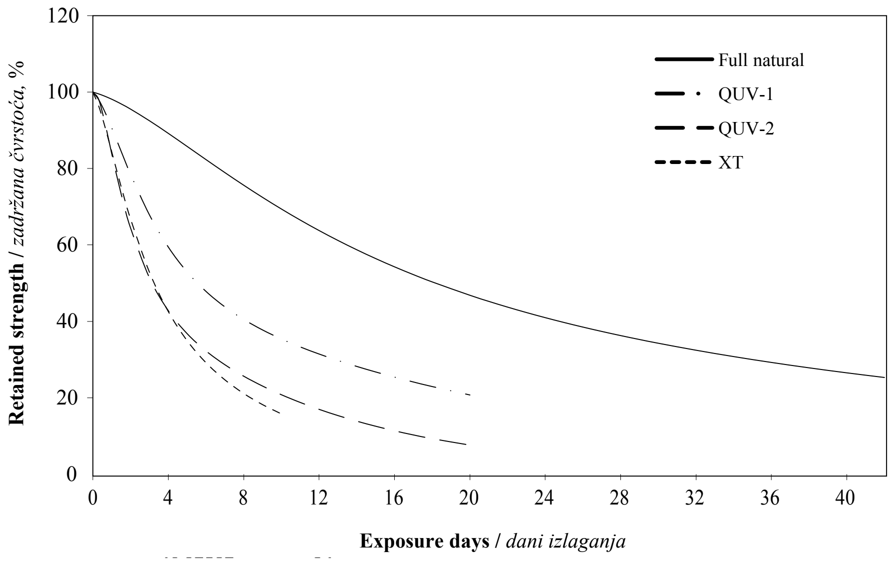

Figure 8 Strength changes of Scots pine sapwood in natural exposure and in artificial weathering regimes (UV and xenon light) of high humidity tested over 10 mm span
Slika 8. Promjene čvrstoće bjeljike bijele borovine tijekom prirodnog izlaganja i laboratorijskog izlaganja (UV i ksenonskom svjetlu) pri visokoj relativnoj vlažnosti zraka ispitivane na 10 mm rasponu

The integration of the results yielded by microtechnique to the gross sample properties is impossible. However, microspecimens serve as useful link between the single fibre and the standard size specimen. Further to that, microtensile testing presents a very beneficial technique as additional analysis method of wood mechanical, chemical and biological properties.

Provided that specimens are of small dimensions so that anatomical differences might be large in comparison with overall dimensional values, the application of the method enables a rapid and reliable means of assessing the complex chemical and structural changes occurring within the surface layers of wood during weathering as well as depth profiling during other degradation or modification processes.

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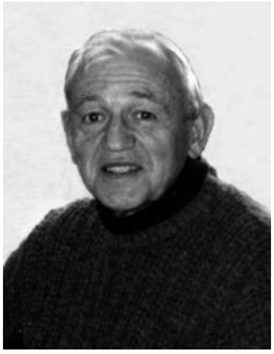
Prof. dr. sc. Marijan Brežnjak
professor emeritus
(Zagreb, 27. travnja 1926. – Zagreb, 16. siječnja 2014.)



U Zagrebu je 16. siječnja 2014. u 88. godini preminuo prof. dr. sc. Marijan Brežnjak, prof. emeritus, umirovljeni nastavnik Šumarskog fakulteta u Zagrebu, znanstvenik i stručnjak, doajen drvnotehnološke struke s područja pilanarstva.

S boli i tugom 23. siječnja 2014. godine na zagrebačkom Mirogoju okupila obitelj, rodbina, prijatelji, kolege i pripadnici drvnotehnološke struke te ga ispratili na posljednji počinak.

Prof. Marijan Brežnjak rođen je 27. travnja 1926. godine u Zagrebu od oca Stjepana i majke Marije, rođene Poslon. U Zagrebu je završio osnovnu školu te maturirao na Prvoj muškoj realnoj gimnaziji. Na Šumarskom odjelu, Tehničkom smjeru, Poljoprivredno-šumarskog fakulteta u Zagrebu diplomirao je 1952. godine stekavši zvanje diplomiranog inženjera šumarstva.

Nakon završetka studija radio je u drvnoindustrijskim poduzećima u Klani i Delnicama. Godine 1955. izabran je za asistenta iz predmeta Pilanska prerada drva u Zavodu za tehnologiju drva Poljoprivredno-šumarskog fakulteta u Zagrebu. Doktorat šumarskih znanosti, s područja pilanske prerade drva stekao je 1964. godine. Za docenta je izabran 1971., za izvanrednog profesora 1972., a za redovitog profesora 1977. godine.

Na Katedri za tehnologiju drva Drvnotehnološkog odjela Šumarskog fakulteta Sveučilišta u Zagrebu radio je i stjecao odgovarajuća akademska zvanja sve do odlaska u starosnu mirovinu 1991. godine.

Kao veliki entuzijast u svome poslu, i nakon umirovljenja nastavio se baviti znanstvenim, stručnim i nastavnim radom s područja pilanarstva kao nositelj predmeta na diplomskome i poslijediplomskom studiju tijekom nekoliko akademskih godina.

Na Šumarskom je fakultetu, ovisno o znanstvenom statusu i potrebama nastavnog plana, vodio laboratorijske i terenske vježbe te održavao predavanja iz predmeta Pilanska prerada drva i Tehnologija masivnog drva u sklopu dodiplomske nastave.

Na poslijediplomskoj nastavi vodio je studije i predavao predmete za stjecanje zvanja magistra i doktora znanosti s područja tehnologije masivnog drva, odnosno pilanske prerade drva.

Vodio je mnoštvo diplomskih radova te bio mentor za pet uspješno obranjenih doktorata znanosti i deset magisterijskih radova.

Uz rad na Šumarskom fakultetu u Zagrebu, tijekom svoje dugogodišnje nastavne, znanstvene i stručne aktivnosti kontaktirao je i surađivao s nizom svjetski poznatih institucija i znanstvenika. Ta se suradnja očitovala u brojnim znanstvenim i stručnim radovima i raspravama objavljenima na više jezika u hrvatskim i svjetskim znanstvenim i stručnim časopisima ili u posebnim publikacijama, te mnogobrojnim predavanjima, kraćim ili duljim posjetima raznim svjetskim istraživačkim centrima s područja drvne tehnologije i tehnike.

Više je puta bio na studijskim boravcima u Norveškoj, i to na Drvnotehničkom institutu u Oslu i na Odjelu za tehnologiju drva pri Visokoj poljoprivrednj školi, u Aasu, gdje je kao gostujući profesor držao i nastavu.

Kao ekspert za pilanarstvo organizacije FAO i Ujedinjenih naroda godinu je dana boravio i radio u Rangoonu, u Burmi, gdje je kao savjetnik za unapređenja tamošnjeg pilanarstva izradio niz odgovarajućih studija, projekata i ekspertiza za vladu Burme.

Osim toga, posjetio je te često i održao predavanja i u ovim institucijama:

- u Laboratoriju za šumske proizvode Kalifornijskog sveučilišta u Berkeleyu (SAD)
- u Institutu za drvo u Madisonu (Winsconsin - SAD)
- u Laboratoriju za šumske proizvode u Princes Risboroughu (Velika Britanija)
- u Institutu za istraživanja na području tehnologije drva u Münchenu (Njemačka)
- na Visokoj drvarskoj školi u Zvolenu (Slovačka)
- u Institutu za drvo u Bratislavi (Slovačka)
- u Švedskom institutu za istraživanja na području tehnologije drva u Stockholmu (Švedska)
- u Laboratoriju za istraživanja na području drvne tehnologije u Tampereu (Finska)
- u Tehničkom centru za drvo u Parizu (Francuska)
- u Odjelu za drvo Sveučilišta u Kyotu (Japan)
- u bivšoj Jugoslaviji: u Ljubljani, na Lesarskom odelku Biotehničkog fakulteta te u Sarajevu i Beogradu.

Nekoliko je puta organizirao i vodio studijska putovanja stručnjaka iz hrvatskih i slovenskih drvnoindustrijskih poduzeća u odgovarajuće pogone u Norveškoj i Švedskoj.

U akademskim godinama 1972. – 1974. bio je prodekan Drvnoindustrijskog odjela Šumarskog fakulteta, a od 1981. do 1983. i dekan Šumarskog fakulteta Sveučilišta u Zagrebu.

Bio je dugogodišnji predstojnik Katedre za tehnologiju drva Šumarskog fakulteta, kao i dugogodišnji član Upravnog odbora i Redakcijskog savjeta časopisa "Drvna industrija", a kraće je vrijeme obnašao i dužnost glavnog urednika tog časopisa. Bio je i član Uredničkog odbora Šumarskog lista za stručno područje pilanske prerade drva. Povremeno je na

Fakultetu te u različitim strukovnim organizacijama u Zagrebu obavljao i niz drugih odgovarajućih poslova.

Obnašao je i mnoge funkcije u raznim internacionalnim stručnim organizacijama. Tako je od 1972. do 1974. godine bio predstavnik tadašnje Jugoslavije u Tehničkom savjetu SEV-a u Bratislavi. Neko je vrijeme bio predstavnik bivše Jugoslavije u Komitetu za drvo pri Ujedinjenim narodima. Od 1976. do 1984. godine bio je član Internacionalnog savjeta IUFRO-a, u svojstvu predsjednika jedne od sekcija. Aktivno je sudjelovao na pet svjetskih kongresa IUFRO-a (u Oslu 1976.; u Kyotu 1980.; u Ljubljani 1985.; u Montrealu 1990. i u Tampereu 1995.). Održao je referat i na Internacionalnoj konferenciji IUFRO-a, Sekcije za drvne proizvode u Oxfordu (Velika Britanija).

Objavio je, sam ili u suradnji s drugima, više od 100 znanstvenih i stručnih radova, 18 stručno-informativnih radova, 12 ekspertiza i projekata, 22 prijevoda i prikaza iz strane znanstvene i stručne literature, četiri udžbenika te veći broj kraćih ili duljih informativnih radova. Radovi su mu objavljeni u raznim znanstvenim ili stručnim domaćim i stranim publikacijama, na hrvatskome, engleskome, njemačkome i norveškom jeziku.

U mnogim gradovima Hrvatske i diljem svijeta održao je više od 30 javnih predavanja. Osim toga, napravio je niz recenzija te izradio brojne interne stručne studije i razne pisane materijale kao pomoć studentima u učenju.

Jedini je u Republici Hrvatskoj u jednom hrvatskom i jednom njemačkom znanstveno-stručnom časopisu objavio dokumentirane podatke o štetama drvnoindustrijskih poduzeća u Hrvatskoj, nastalima tijekom Domovinskog rata.

Za svoj cjelokupni znanstvenoistraživački, stručni i nastavni rad dobio je velik broj priznanja:

- 1989. godine od Zagrebačkog je sveučilišta dobio Priznanje zaslužnog profesora
- 1997. godine izabran je za počasnog člana Akademije šumarskih znanosti
- 1998. godine dobio je Povelju Šumarskog fakulteta Sveučilišta u Zagrebu, za osobit doprinos razvoju i promicanju šumarske nastave i znanosti u Republici Hrvatskoj
- 1999. godine dobio je Zahvalnicu časopisa Drvna industrija
- 2000. godine od Zagrebačkog je sveučilišta izabran u akademsko zvanje Professora emeritusa
- 2005. godine, na 2. drvnotehnološkoj konferenciji, održanoj u Opatiji, dobio Priznanje za životni doprinos razvoju drvnog sektora.

I u svojim neformalnim aktivnostima prof. Marijan Brežnjak bio je iznimno zanimljiva i društvena osoba. Plijenio je svojom jednostavnošću i prisnošću. Uvijek je bio spreman savjetovati i pomoći u održavanju nastave, napredovanju, pisanju ili objavljivanju radova. Kad god mu je zdravlje dopuštalo, vrlo se rado odazivao na razna druženja s kolegama iz gimnazijskih dana, s kolegama na fakultetu i s članovima Hrvatskoga šumarskog društva.

S obzirom na vrlo bogato životno iskustvo, bio je nadasve zanimljiv sugovornik i predavač. Kada se kao profesor u mirovini ponovo aktivirao u nastavi, studenti bi me često pitali kada će opet doći održati predavanje onaj „stari zanimljivi profesor“. Nažalost, toga više neće biti.

Svijetli lik i djela prof. Marijana Brežnjaka ostat će trajno upisana u anale Šumarskog fakulteta te u mislima i srcima onih koji su ga poznavali, družili se s njim i cijenili ga kao jednoga od najvećih doajena drvnotehnoloških znanosti na ovim prostorima.

Neka mu je vječna hvala.

doc. dr. sc. Josip Ištvanić

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Kao najbliža svjedokinja pokojnikova života i karijere zahvaljujem prof. dr. Josipu Ištvaniću na tekstu *In memoriam* kojim je rezimirao rad svoga dugogodišnjeg kolege, profesora i mentora, rad koji samo struka može na pravi način vrednovati.

Ono što treba dodati, jest nešto o prof. Brežnjaku kao čovjeku, a što znaju samo bliski prijatelji, kojih više nema mnogo, i obitelj: Marijan Brežnjak bio je vjerojatno jedini „drvarac“ među umjetnicima ili ponajveći nesuđeni umjetnik među tzv. drvarcima. Kad kažem riječ *umjetnik,* mislim na njegov osviješteni osjećaj prema samoj umjetničkoj biti *života*. Mislim time na stvaralački, osjećajan odnos prema uvijek novoj i uzbudljivoj svakodnevici, prema zajedničkome, (ne)običnom, sveljudskom iskustvu koje je za njega uvijek bilo nekako poetsko, jedinstveno, začudno, uvijek intenzivnije i bogatije od iskustva prosječnih ljudi.

Da parafraziram Thomasa Manna: *bio je pomalo umjetnik izgubljen u građanskom životu*, a opet previše znanstvenik, previše sustavan i „doslovan“ da bi bio u potpunosti - umjetnik. Recimo, na primjer, samo to da je želio biti slikar, a nije primljen na akademiju i postao je, zacijelo ne posve slučajno, šumar i tehnolog. Ili spomenimo i to da je posljednjih godina pisao polufikcijske memoare koji, bili oni objavljeni ili ne – otkrivaju onaj poseban odnos prema riječima, dvojbama i pamćenju, tipičnima za pisca. Osim toga, njegovi crteži školskih kolega u *Spomenici maturanata I. muške realne gimnazije u Zagrebu 1946*., objavljenoj uz proslavu 60. obljetnice mature, upravo su izvrsni, kako kažu svi. Akademik Vladimir Stipetić te pokojni Ranko Filjak i Tomica Barišić bili su u gimnaziji ekipa mladog Brežnjaka ne samo za preferans, nego i za izlaske, glazbu, operu, izložbe, za idiličan život srednjoškolaca posljednjih mirnodopskih dana koje će naprasno prekinuti rat.

Neostvareni slikar, ljubitelj glazbe, lijepe književnosti i stranih jezika postao je, stjecajem okolnosti „drvarac“, ali posebnoga kova: doživljavao je drveće kao žive organizme, a drvo je opisivao ne samo kao funkcionalne nego i kao umjetničke oblike, kao preobraženu, produhovljenu prirodu. (Osobito je volio kanadske toteme i turopoljske crkvice od drva koje su ga podsjećale na slične crkvice u Skandinaviji.)

I sam odnos prema drveću, od sekvoja u Kaliforniji do šuma tikovih stabala u Burmi, bio je na neki način (i) pjesnički. Njihov je autor mislio o drvu kao o živoj tvari koja ima veze s umjetnosti, kao i svaka čovjekova kreativna intervencija u prirodi: Tesanje, tokarenje, rezbarenje, funkcionalno ili estetsko oblikovanje drva, prije nego što su postali znanstveno kompjutorizirano istraživanje, bili su nekoć starinska manufaktura, umjetnički obrt. Po pričanju pamtim pilane potočare (tema doktorata) i prvi posao mladog inženjera u „bespućima“ gorskokotarskih prašuma, u kojima se osjećao kao traper ili istraživač - sve mu je bilo uzbudljivo, novo, pustolovno. I taj ga osjećaj strasnog zanimanja za romanesknu bit priča koje nam život ispisuje nije nikada napuštao.

Unuk djeda s „mustačima“ iz Podbele, iz „hiže s podom od nabijene zemlje“, sin obrtnika iz donje Ilice i mame što je došla za službom iz Krapine, najstariji brat u obitelji s dvije sestre, bio je „mali uplašeni Zagorac“, kako je o sebi volio govoriti bez imalo koketerije. No taj će isti čovjek kao stručnjak i znanstvenik kasnije obići velik dio svijeta i najdulje boraviti u Norveškoj, koja je postala dio njegove kulture i osobnosti. Poezija Sjevera, skijanja na zamrznutim jezerima, ugođaj toplih šumskih koliba i tragovi ženskih krplji u snijegu bili su središnji dio njegove imaginacije, kao i nezaboravna iskustva Burme i južnoazijskoga „vodenog“ potkontinenta.

Životopis buran, bogat i po osobitom načinu doživljavanja romantičan – ne u smislu kičastog pretjeravanja, nego iskrenog oduševljenja za ljude, žene, krajolike, za strana podneblja i kulture koje je empatijski upijao i o kojima je do kraja života maštao. Zahvaljujući svojoj dobokoj osjećajnosti i dobroti.

A pisac je u njemu cijelo vrijeme čekao, kao i onaj pritajeni slikar.

Volio je tako Kraljevića i Račića, francuske impresioniste; nije volio apstrakciju, Picassa ni kubiste, bili su mu previše konceptualni. Volio je Pariz, koji je za njega bio romantičniji od Londona i Beča. Volio je Matoša i Ujevića, Verlainea i Baudelairea, a posebno njegov stih koji je prigrlio doslovce kao svoj životni moto, a koji glasi: „Treba uvijek biti pjan (...) Od vina, pjesništva ili vrline, kako vam drago. No opijajte se.“

Bio je po tome pomalo nalik na onog „cvrčka“ iz basne (kako ga je zvao Tomica Barišić, najbolji prijatelj i kolega), uvijek s izraženom intuicijom za sadašnjost trenutka, bez primisli na „vjetar sjeverac“ koji ga je na kraju ipak odnio.

„Odilazim za vihora što nosi me poput lista“ ... bio mu je drugi najdraži stih.

*

Kao primjer navedenoga odabrali smo ulomak iz članka prof. Brežnjaka *Drvo – taj divni materijal* (Šumarski list br. 5-6/96, str. 219-224) iz kojega je razvidna sljubljenost znanstvenika sa svojom materijom, kao i nadahnuti „pogled“ pisca.

Drvo, kao materijal, dakle kao materija od koje nešto proizvodimo, proizvod je ***živog organizma*** *– stabla, šume, prirode. Kad kažemo: proizvod je živog organizma, to znači nečega što se na određeni način rađa, što raste, što se razvija pa i umire, zar to ne izaziva neko strahopoštovanje! Kakav odnos ima čovjek prema tom stablu, prema drvu kad je već stablo izgubilo (ili su mu ljudi oduzeli) životne funkcije?!* (...)

Interesantno je, i za nas danas, kako je čovjek *dok je još stvarao – pa i pomoću drva – uvjete svog opstanka na Zemlji, a pogotovo kasnije kad je takve osnovne uvjete već osigurao, imao osjećaj,* ***čak potrebu za estetskim, umjetničkim oblikovanjem drva i proizvoda od drva****. Podsjetimo se na smirene i monumentalne (iako u relativno malim dimenzijama) drvene egipatske sarkofage te likovna i druga oblikovanja na njima; na vikinške upravo nevjerojatno elegantne vitke brodove s ponekad zastrašujućom glavom na izduženom pramcu. Kad govorimo o brodovima, ne možemo a da se ne podsjetimo i na danas još ploveće, uske, s osjećajem za spoj funkcionalnog i lijepog, iz tikovih debala izdubene čamce u deltama Iravadi, Mekonga i drugdje. Pogledajmo i iz drva maštovito izrađenu raznu opremu za lov i ribolov, za hodanje po snijegu koju koriste Laponci; neki se od tih predmeta doimlju kao da služe samo za ukras. Koga može ostaviti hladnim pogled na konstrukciju asketske arhitekture, na stotine godina stare crkve izgrađene u Norveškoj iz debala i dasaka bora i smreke, čiji se zvonici (kao u kamenoj gotici) simbolički izvijaju prema nebu.*

Podsjetimo se i na naše – po dimenzijama skromnije – ali u svojoj jednostavnoj rustikalnosti lijepe hrastove crkvice u Turopolju i drugdje, sa svojim nepretencioznim ali skladnim niskim piramidalnim zvonicima. Zadivljuju nas prastare, još i danas prkoseći vremenu, skladne, znalački iz hrastovih tesanih planki izgrađene kuće u Pokuplju, Slavoniji, Hrvatskom zagorju. Ostajemo upravo zapanjeni pred nevjerojatnom istočnjačkom maštom i vještinom prebogato ukrašenih i izrezbarenih, danas već zapuštenih palača usred Katmandua, izrađenih iz tikovine, ili drugih, na vremenske utjecaje otpornih vrsta drva... I tako bismo mogli nastaviti s nabrajanjem primjera diljem svijeta o korištenju drva u ljudskoj povijesti, ne samo kao izvanrednog materijala za zadovoljavanje najrazličitijih životnih potreba, nego i za ***duboko u čovjeku usađenu potrebu za duhovnim izražavanjem, za stremljenje prema lijepome… (...).***

Tako je važno pitanje u vezi s drvom o kojem raspravljamo, pitanje njegova korištenja u njegovoj finalnoj formi. Polazimo od toga ***da je drvo predragocjeni materijal da bismo ga koristili tamo gdje njegove komparativne prednosti pred drugim materijalima ne dolaze do punog izražaja.*** *Pod komparativnim prednostima drva mislimo na estetska svojstva drva (boja, tekstura, čak i određene „greške“ drva), njegovu toplinu u kontaktu s čovjekom, mogućnost lakog oblikovanja* ***i*** *obrade uopće, relativno malu volumnu težinu i druga iznimna svojstva. U tom smislu smatramo da će se masivno drvo u budućnosti koristiti prije svega tamo gdje ono dolazi u izravan ili neizravni doticaj s* ***čovjekom*** *(...).*

Nemojmo stoga previše misliti o drvu kao o obnovljivoj sirovini! Mislimo da treba prihvatiti filozofiju o drvu kao vrlo dragocjenom i skupom materijalu, iz nekih aspekata praktički i neobnovljivom, kojeg kod prerade treba što bolje iskoristiti u proizvodnji razumno odabranih finalnih proizvoda.

Tako kaže autor u zaključku svog osjećajnog razmišljanja o drvu u duhu njegova održivog razvoja na već, nažalost, vrlo opustošenom planetu.

prof. dr. sc. Ingrid Šafranek
Zagreb, 3. veljače 2014.

Studenti Drvnotehnološkog odsjeka predstavili idejna rješenja za opremanje mobilnih kućica

U sklopu nastave predmeta Projektiranje proizvoda od drva, studenti druge godine diplomskog studija, smjera Oblikovanje proizvoda od drva, posjetili su 23. siječnja 2014. Fakultet za dizajn u Ljubljani. Povod tom posjetu bilo je predstavljanje idejnih rješenja za opremanje mobilnih kućica.

Primjer izvedbe cijelog ciklusa razvoja proizvoda, od idejnog rješenja do realizacije prototipa, nije rijetkost u sličnim ustanovama koje obrazuju stručnjake za drvnoprerađivački sektor, pa se takvi primjeri dobre prakse mogu naći na srodnim fakultetima u Bugarskoj, Grčkoj, Slovačkoj, Austriji, Mađarskoj i možda najbolje i najmodernije opremljenoj Njemačkoj, što je potvrđeno i nedavnim posjetom visokoškolskoj ustanovi Berufsakademie u Dresdenu.

Ponukani navedenim primjerima, pokrenut je projekt razvoja proizvoda mobilne kućice. U listopadu 2013. dogovorena je suradnja između tvrtke Lecotech s direktorom Lukom Iličićem, dipl. ing. el. na čelu i izv. prof. dr. sc. Silvane Prekrat, nastavnice predmeta Projektiranje proizvoda od drva. Tvrtka Lecotech, među ostalim, bavi se izradom kontejnera različitih namjena i dimenzija. U sklopu proizvodnog programa tvrtka je iskazala želju za proširenje asortimana na mobilne kućice za odmor te projektnim zadatkom definirala smjernice razvoja novog proizvoda. Pod vodstvom izv. prof. dr. sc. Jasne Hrovatin, u rad je uključen i Fakultet za dizajn iz Ljubljane, s kojim Šumarski fakultet ima dugogodišnju suradnju.

Tvrtka Lecotech financirala je putovanje studenata i nastavnice u Ljubljanu, gdje su prisustvovali prezentaciji ljubljanskih i zagrebačkih studenata. Nakon prezentacije radova održana je korisna diskusija, a budući da je to bio prvi posjet studenata Ljubljani, domaćini su organizirali i razgled kulturnih spomenika Ljubljane, s naglaskom na radove renomiranog arhitekta Jože Plečnika. Studenti su pri tome imali priliku uočiti korisne konstrukcijske detalje koje je Plečnik primjenjivao kako bi zaštitio građevinsku stolariju od brzog propadanja zbog djelovanja atmosferilija. Osim toga, studenti su bili upoznati i s nizom detalja vezanih za kulturnu baštinu Slovenije, kao i s izložbom najstarijega drvenog kotača u svijetu, čija je starost procjenjena na 5200 godina, a do 20. travnja je izložen u Mestnome muzeju u Ljubljani. Studenti su bili zadovoljni, a zbog mogućnosti uvida u rad svojih kolega iz Ljubljane prošireni su im stručni i kulturni vidici.

Rad na razvoju proizvoda nastavlja se na odabranome idejnom rješenju zagrebačkih studenata i trebao bi biti završen do lipnja izradom prototipa mobilne kućice.

Izv. prof. dr. sc. Silvana Prekrat

Studenti i nastavnici obaju fakulteta s predstavnicima tvrtke Lecotech

Izv. prof. dr. sc. Jasna Hrovatin sa studentima na ljubljanskom Tromostovju

IMM COLOGNE 2014

Sajam noviteta i dizajna, prirodnoga i funkcionalnoga

Ove je godine IMM Cologne proslavio svoju 65. godišnjicu!

Sajam je od 1949. godine, otkako traje, do danas postao najprestižnija manifestacija na kojoj se mogu vidjeti najnoviji trendovi u izradi namještaja i opremanju prostora, i to u impresivnome komercijalnom ozračju. Ove je godine IMM Cologne, uz bijenalni LivingInteriors, potvrdio svoje značenje.

Impozantan broj od preko 120 000 posjetitelja iz 129 država svijeta koji su prošetali IMM-om od 13. do 19. siječnja 2014. ponovno je potvrdio da je taj europski sajam namještaja i prateće opreme najvažnija manifestacija u struci, koja početkom svake godine diktira trendove za iduće razdoblje.

Ovogodišnji IMM Cologne obilježavaju ovi podaci: 1208 izlagača iz 52 zemlje svijeta te više od 120 000 posjetitelja, u usporedbi sa 116 000 posjetitelja u 2012, od čega je oko 86 000 njih iz Njemačke, a nešto više od 34 000 iz 129 drugih država svijeta. Najviše posjetitelja zabilježeno je iz Velike Britanije, Francuske, Nizozemske i Italije te iz Kine i SAD-a. Podatak da je 42,5 % ukupnog broja posjetitelja doputovalo iz Azije, Sjeverne Amerike i Europe pokazuje da IMM Cologne/LivingInteriors mobilizira internacionalno tržište i sve prateće industrije u globalnome svjetskom okruženju (sl. 1).

Ove je godine na sajmu prezentirana multiizražajnost i različitost u razinama predstavljanja i u kvaliteti proizvoda. Prema posljednjim podacima za novinare (press release), izjava direktora IMM-a nadasve je optimistična za 2014. glede trgovine namještajem. Pozitivni učinci sajma itekako će utjecati na buduću potražnju, što se već moglo vidjeti po razini posjećenosti na većini izlagačkih štandova (sl. 2).

Slika 1. Detalj sajma IMM Cologne/LivingInteriors

Slika 2. Atmosfera na izlagačkom prostoru tvrtke LINA DESIGN d.o.o. slovenskog dizajnera Damjena Uršića, koji je za svoje uratke dobio čak tri nagrade

Opći pregled trendova za 2014.

Općenito, svi proizvodi postaju udobniji i šareniji, neki detalji viđeni prošle godine nisu promijenili izgled, no pojavilo se i mnoštvo noviteta, većinom prezentiranih u nagrađenim rješenjima.

Ove godine naglasak je bio na predmetima koji stanove transformiraju u domove: u svakom kutku osjeća se toplina, taktilnost, ugođaj, odmor, prirodnost (sl. 3). Unutar LivingInteriorsa naglasak je bio na detaljima kupaonica, dekoraciji zidova, podova, tekstila i rasvjete.

Slika 3. Priroda ulazi u domove u obliku biljaka, masivnog drva i životinjske kože

Globalna mješavina svih stilova, uz dašak romantike

Nasuprot hladnome virtualnom svijetu interneta, korisnici od namještaja očekuju udobnost, prikladne detalje, harmoniju boja, oblika i udobnih pratećih elemenata kojima će ukrasiti svoj dom. Predmeti su pomno odabrani i postavljeni na mjesto koje naglašava autentičnost, izvornost i individualnost korisnika. Unikatnost je na prvome mjestu. Nekadašnje shvaćanje da možete biti modno osviješteni i u „trendu“ tako da pratite i primjenjujete modne detalje na odjeći, ove se godine protegnulo na područje namještaja, tako da kupci sami, prema vlastitim željama i zamislima, „oblače“ dijelove namještaja u boju ili dekore koje žele (sl. 4). Ključna je riječ individualnost!

Slika 4. *Obucite svoj namještaj* – slogan je koji svakom korisniku omogućuje da sam individualno i trenutačno odluči o izgledu svojega doma

Tehnologija i zdravlje

Tehnologija i zdravlje i dalje su nerazdvojni. Konkretno, udobnost i osjećaj korisnosti pridonose prevenciji zdravlja, a da bi postigli sklad i ravnotežu tijela i duha, dizajneri se služe tehnološkim dostignućima, osobito u kupaonici i spavaćoj sobi te u dnevnom boravku. Simbioza prirodnih i ekološki prihvatljivih elemenata, kojima dizajneri daju prednost, upotpunjeni su zelenim oazama (sl. 5), mirisima i mekanim formama, čime se mijenja nekadašnji izgled tih prostora.

Slika 5. Oaze zelenila na štandovima izlagača; tvrtka Bretz

„Spavači“ u zoni udobnosti, odmora i zdravlja

U kontekstu zdravlja i spavanja, ove su godine „spavači“ postigli rekord u popunjenosti izlagačkih površina (sl. 6). „Spavači“, kao i proizvođači ojastučenog namještaja, pomiču horizonte u smislu multifunkcionalnosti i udobnosti. Za razliku od nekadašnjih „idealnih i zdravih položaja pri ležanju i sjedenju“, danas se nude koncepti udobnosti koji su neizostavno ugrađeni u sve proizvode za ležanje i sjedenje. Korisnici ne doživljavaju krevet ili naslonjač kao proizvod za spavanje ili popodnevno drijemanje nego kao cjeloviti koncept zdravoga i relaksirajućeg sustava.

Slika 6. Cjeloviti pristup uređenju štanda i izloženim ekološkim proizvodima za spavanje; grčka tvrtka COCO-MAT

Boje i materijali

Ovogodišnji su trend jake boje, u kombinaciji s drvom te s bijelom, krem i sivom bojom, kao i s pastelnim tonovima, ukratko, dopuštena je mješavina različitih sadržaja i vizualnih akcenata.

Od vrsta drva i boja prevladavaju prirodni uljani tonovi orahovine, hrastovine i jasenovine, uz detalje bijele boje i pastelnih tonova, poput pastelno plave, tirkizne, sive, ružičaste (sl. 7). Osim pastelnim tonovima, brojni su proizvođači svoje proizvode naglašavali akcentima jakih tonova, poput tirkizne i purpurne, crvene, narančaste… (sl. 8).

Slika 7. Igre bojama najbolje su se mogle zamijetiti na ojastučenom namještaju; primjer pastelnih tonova …

Slika 8…i jarkih boja. Proizvođač Leolux poigrao se tirkiznom, crvenom i žutom bojom te ostalim jarkim tonovima.

Nagrađeni proizvodi – Interior Innovation Awards 2014

And the Award goes to... – tako je počinjalo ovogodišnje proglašenje svake od nagrada dodijeljenih proizvodima u kategoriji *Best of best,* a dobilo ju je 15 proizvoda (sl. 9 – 12).

Slika 9. Interior Innovation Award 2014 – Best of Best. Proizvod: sustav polica REBAR; proizvo**đač**: joval GmbH; dizajn: Jonas Schroeder

Slika 10. Interior Innovation Award 2014 – Best of Best. Proizvod: stolac Buzz; proizvođač: Arco BV; dizajn: Bertjan Pot / Arco BV

Slika 11. Interior Innovation Award 2014 – Best of Best. Proizvod: naslonjač namijenjen spavanju NOVA; proizvođač: Rolf Benz AG & Co. KG; dizajn: Joachim Nees

Slika 12. Interior Innovation Award 2014 – Best of Best. Proizvod: serija proizvoda za tuširanje Axor; proizvođač: Hansgrohe SE; dizajn: Front Design AB

U sklopu Interior Innovation Awarda – Selection nagrade dodijeljene su u kategorijama kupaonica i wellnessa; ureda i radnog prostora; gradbenih materijala; kuhinja i kuhinjskih aparata; rasvjete; namještaja; proizvoda za vanjsko uređenje te dekoracije zidova, podova i stropova. Neki od nagrađenih proizvoda prikazani su na slikama od 13. do 16.

Slika 13. Interior Innovation Award 2014 – Selection. Proizvod: aktivna uredska stolica 3DEE; proizvođač: aeris-Impulsmoebel Gmbh & Co. KG; dizajn: aeris-Impulsmoebel Gmbh & Co. KG

Slika 14. Interior Innovation Award 2014 – Selection. Proizvod: konferencijski stolac LOVA; proizvođač: Alfons Venjakob GmbH & Co. KG; dizajn: In-house design

Slika 15. Stolac 0432; proizvođač: Atelier Fesseler; dizajn: Frederic Fesseler

Slika 16. Interior Innovation Award 2014 – Selection. Proizvod: HEY – Light; proizvođač: HEY-SIGN GmbH; dizajn: In-house design

Das Haus – Interiors on Stage 2014 (sl. 17) dizajnerice Louise Campbell ove je godine izazvala velik broj komentara. Pod nazivom *0-100 (Made to measure)* (u prijevodu: napravljeno po mjeri, nap. a.) autorica je evocirala odnose muškarca i žene, njihove potrebe, sličnosti i različitosti, ustaljene navike i obrasce.

Slika 17. Das Haus – Interiors on Stage 2014

Zanimljivo je bilo sagledati čistoću i dubinu prostora bez zidova, oslobođenoga granica i high-tech dostignuća. Naime, suvremena kuća, prema stajalištu Louise Cambell, treba biti odraz potreba muške i ženske strane svakoga od nas, to treba biti prostor koji podrazumijeva toplinu i prirodnost, bez dodira s hladnim tehnologijama s kojima se svakodnevno susrećemo u eksterijeru, u uredima..., riječju, u svim segmentima društva. Dom treba biti upravo suprotno: on je senzualan, ispunjen toplinom i emocijama, prirodnim materijalima, otvoren, u svakom trenutku dostupan, bez granica. Upravo sve ono što zaboravljamo u svakidašnjem životu punome stresa.

Slike od 17. do 20. predočuju neke detalje interijera ovogodišnjega *Das Hausa*.

Slika 18. Kuhinja i alatnica jedan su zid na kojemu se miješaju ručni pribor, alati i posuđe. Sve je otvoreno i na dohvat ruke

Slika 19. Dugački blagovaonički stol namijenjen druženju, raspravama i drugim zajedničkim aktivnostima

Slika 20. Detalj kupaonice otvorene pogledu, bez paravana

Sleep

Izlagači u kategoriji *Sleep* ispunili su dvije izložbene hale. Sektor koji iz godine u godinu jača, na ovogodišnjem je IMM-u, općenito gledajući, zahvaljujući Udruženju proizvođača madraca (Association of the Mattress Industry) i glavnoj temi *Sleep Lounge*, tradicionalno smještenoj u paviljonu 9, bio povezaniji i organiziraniji nego ikad te potpuno usmjeren prema neuromarketinškoj tržišnoj niši.

Uspjehe što ih spomenuta struka doživljava unutar proizvodnje namještaja i opreme može zahvaliti uloženim investicijama i ujedinjenosti na području istraživanja, razvoja i inovacija te otvorenim raspravama i konferencijama koje su se održavale i za vrijeme sajma. Taj je sektor sve jači i veliku pozornost pridaje zdravlju i dobrobiti korisnika (sl. 21).

Slika 21. Detalj iz paviljona 9 – *Sleep*

[d3] Professionals

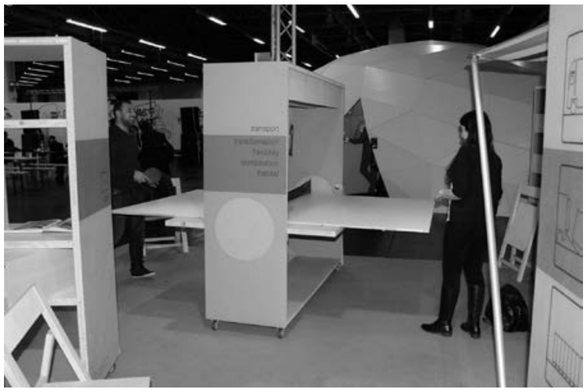
Mladi profesionalni dizajneri izlagali su unutar prostora *[d3] Professionals*. S koje god strane štanda stajali, imali ste priliku vidjeti i osjetiti ideje i koncepte budućnosti. Pobjednik ovogodišnjeg *[d3] Contesta* u sklopu profesionalne kategorije bio je Christoph Goechnahts, koji je osmislio jedinstveni stalak za razne potrepštine i opremu, a namjena mu je u rasponu od vješalice do ormarića.

Slika 22. Pobjednik u kategoriji *[d3] Contest* dizajner Christoph Goechnahts

[d3] Schools

U sklopu projekta *[d3] Schools* predstavili su se studenti dizajna, dizajna interijera i arhitekture sa sveučilišta iz Njemačke i iz ostalih država svijeta (sl. 23. i 24). Taj projekt već niz godina povezuje mlade dizajnerske snage (studente dizajna) i industriju, počevši od proizvodnje, ekonomije i trgovine do ostalih područja gospodarstva. Paviljon *[d3] Schoolsa* oduvijek je bio ispunjen kreativnošću, životom, *moovingom*, inovativnim studentskim idejama, lucidnim dosjetkama i žamorom. Tu nikada nije dosadno, ni izlagačima, ni posjetiteljima. Ako ništa drugo, ove ste godine sa sobom mogli ponijeti komad plastike netom izlivene iz 3D printera (sl. 25) ili lopticu za stolni tenis koja je proletjela pokraj vas (sl. 26). Naime, u sklopu projektnog zadatka studenti su osmislili jedinstvene oblike namještaja u koje su smjestili različite funkcionalne cjeline stana – kuhinju, kupaonicu, terasu, spavaći ili radni prostor, pa čak i stol za ping-pong u sklopu kategorije *Transport (transformation, flexibility, combination, habitat)*.

Može se zaključiti da ovogodišnji trendovi na IMM Cologne/LivingInteriors pomiču granice i otvaraju nove mogućnosti individualnoga kreativnog izražavanja i osobnih, nebrojenih mogućnosti kombiniranja materijala i elemenata namještaja. U odabiru i oblikovanju prostora prema vlastitim željama kombinacije boja su neobuzdane. Nespojivi materijali postaju spojivi i u takvim kombinacijama stvaraju sasvim nove prostorne dojmove i tople, neobične ugođaje. I dalje – sve je dopušteno, sve je moguće. Individualnost je na prvome mjestu.



Slike 23 – 26. Atmosfera na *[d3] Schoolsu*

Iduće godine na bijenalnom će IMM Cologneu/LivingKitchenu, u razdoblju od 19. do 25. siječnja 2015, nastupiti proizvođači i dizajneri kuhinjskog namještaja i opreme.

Izdvojeni kutak – štand hrvatskih izlagača na *IMM Cologneu 2014*

Na sajmu su i ove, kao i posljednjih nekoliko godina, sudjelovale hrvatske tvrtke proizvođači, i to u organizaciji Hrvatske gospodarske komore i uz financijsku potporu Ministarstva poljoprivrede. Riječ je o12 tvrtki (Lapibus, Inkea, DIN Novoselec, Drvni klaster sjeverozapadne Hrvatske – Varaždin, Efektiv, IO Dizajn, FinvestCorp, Noona, Malagić i Sportex) koje su uspješno izložile svoje proizvodne programe većinom od cjelovitog drva – hrastovine i bukovine, te kože i tekstila.

Ove godine naglasak je bio na dizajnu, što se moglo zaključiti i po odabranim izlošcima (sl. 27 – 31).

Slika 27. DIN Novoselec već tradicionalno izlaže suvremene garniture za opremanje blagovaonica i dnevnih boravaka, kao i proizvođači okupljeni u Drvnom klasteru sjeverozapadne Hrvatske

Slika 28. Proizvođač Noona izložio je program dječjih krevetića koji dimenzijama „rastu” s djetetom

Slika 29. Proizvođač Efektiv iz Vinkovaca domišljato je iskoristio i oblikovao panjeve i ležaljku od cjelovitog drva

Slika 30. Zagrebačka Inkea već nekoliko godina izlaže na IMM Cologneu. Ove godine je izložila uredski namještaj LIR

Slika 31. Tvrtka FinvestCorp u svojoj je paleti proizvoda pokazala pravo osvježenje. Dizajner Mario Dobrečević poigrao se oblicima, a čeka ga dorada toga zanimljivog prototipa u smislu funkcionalnosti i ergonomije. Taj bi proizvod, koji krasi poznata i priznata kvaliteta FinvestCorpove proizvodnje, nesumnjivo mogao doživjeti veću seriju.

Kao i proteklih godina, tvrtka Kvadra izložila je svoje proizvode u drugom paviljonu. Bez obzira na to što je promijenila ime u *Prostorija*, bivša je Kvadra i ove godine dobitnik nekoliko nagrada (Interior Innovation Award 2014) za proizvode nastale u suradnji s hrvatskim dizajnerima (sl. 32 – 33). Čestitamo!

Slika 32. Izlagački prostor tvrtke Prostorija, bivše Kvadre

Slika 33. Nagrađeni preklopni naslonjač dizajnera Nevena i Sanje Kovačić dizajniran za tvrtku Prostorija

Četvrti put zaredom, samostalno kao i spomenuta Prostorija, izlagala je i hrvatska tvrtka Prima namještaj. Riječ je o tvrtki s dugogodišnjom tradicijom u proizvodnji, maloprodaji i veleprodaji kućnog namještaja koja se, ne bez razloga, ubraja među najveće hrvatske proizvođače. Ove godine Prima se predstavila novitetima za koje se nada da će ostvariti izvozni plasman na već utvrđena tržišta desetak europskih zemalja i time potvrditi svoju misiju – ostati pouzdan strateški partner koji kontinuiranim praćenjem tržišnih kretanja, unapređenjem proizvodnje te praćenjem i oblikovanjem trendova ispunjava zahtjeve svojih klijenata i kupaca.

Ujedno čestitamo svim hrvatskim izlagačima koji su ove godine dali izniman doprinos udjelom dizajna u svojim proizvodima i time dokazali da se dizajnom itekako može razviti i realizirati dobar proizvod koji povećava konkurentnost hrvatskih proizvođača namještaja, ali i cijele Hrvatske.

dr. sc. Danijela Domljan, magistrica dizajna
prof. dr. sc. Ivica Grbac
fotografije: dr. sc. Danijela Domljan; materijali za novinare IMM Colognea 2014

PADOUK

UDK: 674.031.739.362

NAZIVI I NALAZIŠTE

Drvo vrste *Pterocarpus soyauxii* Taub. iz botaničke porodice *Leguminosae* potječe iz zapadne Afrike: Nigerije, Kameruna, Gvineje, Gabona, Konga, Angole. Široko je raspostranjeno u tropskim kišnim šumama. Trgovački i lokalni nazivi su mu african padouk, barwood (Velika Britanija); Afrikanisches Padouk, Afrikanisches Korallenholz (Njemačka); bois corail, padouk (Francuska); africaans padoek (Nigerija); takula (Angola); mbel, ebeu (Gabon); ba, corail, mohingué, muengé, ndimbo (Kamerun); boisulu, kisésé, ngula, wele (Kongo); arapka (Nigerija).

Unutar roda *Pterocarpus* Jacq. poznato je 35 vrsta, od kojih su neke prirodno rasprostranjene u južnoj Africi i Aziji, a na tržištu se pojavljuju pod različitim nazivima.

STABLO

Drvo vrste *Pterocarpus soyauxii* Taub. listača je srednje visine, između 30 i 40 m. Promjer debla kreće se između 80 i 100 cm, rjeđe i do 120 cm. Debla su cilindrična, obično čista od grana, vrlo visoka, što omogućuje dobivanje trupaca velike tehničke duljine.

Visina do prve grane iznosi 15 do 20 m. Kora je raspucana, a sa starenjem se ljušti. Debljina kore kreće se od 0,5 do 1,0 cm.

DRVO

Makroskopska obilježja

Srž i bjeljika jasno se razlikuju po boji. Bjeljika je široka, bjelkasta do krem boje. Sirova je srž žarko crvena do crvenosmeđa, stajanjem postaje tamnosmeđe crvena, sa svjetlijim crvenim prugama.

Drvo je do fine srednje grube teksture. Žica drva je ravna, katkada i uskukana. Svježe je drvo aromatičnog mirisa (blagi miris vanilije).

Granica goda je dobro uočljiva. Pore i aksijalni parenhim okom su vidljivi, a drvni su traci jedva uočljivi povećalom.

Mikroskopska obilježja

Drvo je rastresito porozno. Pore su pretežno pojedinačne i u paru, rjeđe u radijalnim skupinama. Promjer pora iznosi od 150...260...315 mikrometara. Gustoća pora iznosi 1 – 2 /mm^2 poprečnog presjeka. Volumni udio pora je oko 9 %. Pore mogu biti ispunjene smeđim sadržajem. Aksijalni je parenhim apotrahealno vrpčast, paratrahealno vazicentričan, konfluentan do vrpčast.

Udio aksijalnog parenhima iznosi oko 23 %. Staničje drvnih trakova je homogeno. Drvni su traci katnog rasporeda. Visoki su od 6 do 10 stanica, a široki 1 stanicu. Gustoća trakova je 12...14...17 po mm poprečnog presjeka. Udio drvnih trakova iznosi oko 13 %. Vlakanca su libriformska i vlaknaste traheide. Debljina stijenki vlakanaca kreće se od 2,95...3,8 do...5,5 mikrometra, a promjer lumena je 2,2...11,2...17,6 mikrometara. Duljina vlakanaca iznosi 1035...1380...1660 mikrometara. Volumni udio vlakanaca kreće se oko 55 %.

U stanicama trakova i aksijalnog parenhima nalaze se kristali prizmatičnog oblika. U pojedinoj se stanici nalazi jedan kristal. Stanice s kristalima normalne su veličine. U stanicama drvnih trakova nema silicija.

Fizikalna svojstva

Gustoća standardno suhog drva, ρ_0	oko 650 kg/m^3
Gustoća prosušenog drva, ρ_{12-15}	650...700...850 kg/m^3
Gustoća sirovog drva, ρ_s	950...1000...1050 kg/m^3
Poroznost	oko 57 %
Totalno radijalno utezanje	2,6...3,6 %
Totalno tangentno utezanje	4,1...5,4 %
Totalno volumno utezanje	6,4...10,6 %

Mehanička svojstva

Čvrstoća na tlak	67,4...74,8...81,5 MPa
Čvrstoća na savijanje	123,5...137,5...166 MPa
Čvrstoća na vlak okomito na vlakanca	1,9...2,4 MPa
Tvrdoća prema Brinellu paralelno s vlakancima	oko 80 MPa
Tvrdoća prema Brinellu okomito na vlakanca	oko 40 MPa
Modul elastičnosti	11,1...14,4 GPa

TEHNOLOŠKA SVOJSTVA

Obradivost

Drvo se nešto teže obrađuje ručnim alatima, no strojno se obrađuje lakše. Preporučuje se uporaba oštrih alata kako bi se izbjeglo čupanje i mrvljenje drva. Drvo se dobro brusi, buši, ljušti i lijepi. Bruševina može prouzročiti dermatitis. Prije upotrebe vijaka preporuča se predbušenje drva. Zbog veće gustoće drva lijepljenje treba pažljivo obaviti.

Sušenje

Drvo se suši dobro, uz vrlo malo grešaka ili bez njih. To su uglavnom neznatne pukotine i blaga iskrivljenost. Trupce za sušenje treba pažljivo složiti i omogućiti dobru cirkulaciju zraka. Stabilnost dimenzija je dobra, a jednom prosušeno drvo umjereno radi.

Trajnost i zaštita

Prema normi HRN 350-2, 2005, srž drva vrlo je otporna na gljive truležnice (razred otpornosti 1). Otpornost srži na tercijarne kukce klasificirana je kao trajna (razred otpornosti 2), dok je bjeljika podložna napadu tercijarnih kukaca. Bjeljika je srednje permeabilna (razred 2).

Prema normama, drvo padouka može se bez problema upotrebljavati u razredu opasnosti 4 bez ikakve kemijske zaštite. Srževina dobro podnosi rizike od povremenoga ili trajnog vlaženja, a čak se može rabiti i u razredu opasnosti 5 (kad je u dodiru sa slanom vodom ili morem).

Uporaba

Drvo se iskorištava za proizvodnju furnira, za izradu unutarnje i vanjske stolarije, kvalitetnog namještaja, izradu parketa, brodova (drvena rebra), mostova (dijelovi u dodiru s vodom ili tlom) te za izradu željezničkih pragova. Odlikuje se visoko-rezonantnom kvalitetom i u Africi je cijenjeno kao drvo za izradu bubnjeva. Zbog velike stabilnosti dimenzija, od tog se drva izrađuju podne obloge u javnim prostorima u kojima je prohodnost velika. Ekstrakti kore prerađuju se u medicini i kozmetici.

Sirovina

Drvo dolazi u obliku trupaca i u obliku piljene građe. Trupci su obično većih dimenzija.

Napomena

Drvu vrste *Pterocarpus soyauxii* zasad ne prijeti uništenje. Nije na popisu CITES (Convention on International Trade in Endangered Species), niti na popisu IUCN (International Union for Conservation of Nature and Natural Resources) kao ugrožena vrsta, za razliku od nekih vrsta istog roda s područja Azije.

Vrste drva sličnih svojstava jesu: *Pterocarpus cambodianus* Pierre, *P. indicus* Wild., *P. macrocarpus* Kurz., *P. marsupium* Roxb., *P. pedatus* Pierre, *P. angolensis* DC., *P. dalbergoides* Roxb.

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Upute autorima

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Author's second name, initial(s) of the first name, year: Title. (ev. Publisher/editor): edition, (ev. volume). Place of publishing, publisher (ev. pages from - to).

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Wilson, J.W.; Wellwood, R.W. 1965: Intra-increment chemical properties of certain western Canadian coniferous species. U: W. A. Cote, Jr. (Ed.): Cellular Ultrastructure of Woody Plants. Syracuse, N.Y., Syracuse Univ. Press, pp. 551-559.

Other publications (brochures, studies, etc.):
Müller, D. 1977: Beitrag zur Klassifizierung asiatischer Baumarten. Mitteilung der Bundesforschungsanslalt für Forst- und Holzwirtschaft Hamburg, Nr. 98. Hamburg: M. Wiederbusch.

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