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Radosław Mirski, Jerzy Majka, Dorota Dziurka[1]

The Effect of Residual Swelling after Drying on Internal Bond in OSB

Utjecaj trajne promjene debljine zbog bubrenja na čvrstoću raslojavanja OSB drvnih ploča

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ABSTRACT • *The study determined the effect of non-recoverable thickness swelling (NTS) on internal bond in oriented strand boards (OSB). The tests were conducted taking into consideration different time variants, ranging from 1 to 70 h, of soaking in water at 20ºC. The analysis of the results recorded for measured non-recoverable thickness swelling indicates that the observed reduction of strength is a result of changes occurring in the core of boards. Moreover, a linear IB/NTS dependence was observed for OSB/3 and OSB/4 of 15 mm in thickness.*

***Keywords**: OSB, thickness swelling, internal bond, non-recoverable swelling*

SAŽETAK • *U radu je analiziran učinak trajne promjene debljine zbog bubrenja (NTS) na čvrstoću raslojavanja drvnih ploča s orijentiranim iverjem (OSB). Ispitivanja su provedena uzimanjem u obzir vremena natapanja uzoraka u rasponu od 1 do 70 sati u vodi pri temperaturi 20 °C. Analiza rezultata dobivenih za trajne promjene debljine zbog bubrenja pokazuje da je zabilježeno smanjenje čvrstoće posljedica promjena koje se događaju u središtu drvne ploče. Rezultati su pokazali linearnu ovisnost čvrstoće raslojavanja o vrijednosti trajne promjene debljine za ploče OSB/3 i OSB/4 debljine 15 mm.*

***Ključne riječi**: OSB drvne ploče, debljina nakon bubrenja, čvrstoća raslojavanja, trajna promjena debljine ploče*

1 INTRODUCTION
1. UVOD

A vast majority of wood-based materials (over 90%) are composites of comminuted wood and a binding agent bonding these comminuted fragments. The degree of comminution has a decisive effect on mechanical properties of the produced material and it determines its price. The greater the degree of combination, the less advantageous are the mechanical properties, but at the same time also the lower is the price of such materials. A lower price results from the fact that inferior quality wood may be used, frequently already comminuted, coming from thinning of waste in forests or from waste wood from other branches of industry. The type of the applied binding agent determines the degree of resistance to external environmental conditions in a given material and defines its applicability in the broadly understood construction business. Binding agents, providing adequate water resistance of wood-based materials, include synthetic resins based on phenol (Andersen and Troughton, 1996; Irle and Bolton, 1988; Amen-Chen *et al*. 2002), melamine and isocyanate adhesives (Brochmann *et al*., 2004). Wood-based materials bonded us-

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ing these adhesives, particularly plywood, V100 boards and OSB, are applied wherever, apart from strength, high moisture resistance is also required. Due to their advantageous price, in recent years the value ratio of OSB has been predominant in the construction industry (Hikiert, 2001; Oniśko, 2002), replacing plywood in many applications. However, high mechanical properties of these boards (Brinkmann, 1979; Zhou, 1990; Nishimura *et al*., 2001; Han *et al*., 2005) as well as their considerable moisture resistance (Gu *et al*. 2005; Mirski *et al*., 2011; Wu, 1999) do not guarantee high linear expansion stability. Changes caused by moisture in linear dimensions of boards result from hygroscopic properties of wood. Linear expansion in OSB subjected to the action of humid air has been investigated in many studies (Wu, 1999; Suchsland, 2000; Lee and Wu, 2002; Mirski, 2007). In practice, much importance is attributed to changes in thickness. Swelling of boards is caused by very many factors, primarily mat quality, including wood species, chip quality, orientation, the number of layers and their weight ratios, type of resin (formulation, amount applied) as well as used hydrophobic agents (Halligan, 1970; Liu and McNatt, 1991; Mirski *et al*., 2011). In recent years attention has been focused on the effect of the proportion of swelling in individual layers on total swelling in thickness. This contributed to the patenting of optical measurement of changes in thickness proposed by Wang and Winistorfer (2002). It results from studies presented by Wang and Winistorfer (2003) and Wang *et al*. (2003) that, in case of OSB, the share of swelling in face layers is dominant. The share of swelling in face layers and the core changes with soaking time. Thus after 2 h soaking it reached 74 % of total swelling, while after 24 it reached only 57 % of total swelling (Wang and Winistorfer, 2003). Changes in thickness of boards related with changes in its moisture content may be divided into two types: recoverable thickness swelling (RTS) and non-recoverable thickness swelling (NTS) (Halligan, 1970; Wu and Suchsland, 1997). Total thickness of the board deformation caused by changes in the moisture content can be divided into two components: RTS, this is the part of the deformation of the board thickness which disappears after drying the sample to the initial conditions, NTS is a strain that remains despite the loss of force (although the initial humidity is restored).

Residual deformations remaining after the wetting process are generally a consequence of damage to the glue lines as a result of stresses formed in the wetted material (Suchsland and Xu, 1991).

A measure of glue line quality in wood-based materials, with the exception of veneer-based boards, such as PB, MDF and OSB, is established by the determination of internal bond (Dai *et al*., 2008). This method of quality appraisal for glue lines in OSB subjected to wetting and drying processes was presented in their study by Wu and Piao (1999). They showed that IB in boards subjected to the process of wetting or soaking is proportional to residual deformations. The above mentioned authors conditioned boards, dried at 105 ºC, to a specific moisture content or soaked them for a specific time (from 1 h to 24 h), and then dried them again at 105 ºC. The differences in thickness between the absolutely dry state before the wetting process and after this process were considered to be NTS. However, it seems that drying under such harsh conditions already causes a certain degradation of the glue lines. Thus the aim of this study was to state whether the previously observed dependence might also be observed, in a situation in which, after the soaking process, samples were led to initial moisture content in the process of the free drying process. Thus the insight into the behaviour of soaked and dried boards could be significant in practice.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

Tests were conducted on two types of OSB produced on the commercial scale for the applications in the construction industry, i.e. OSB/4 of 8, 15 and 22 mm in thickness, and OSB/3 of 15 mm in thickness. Moreover, both types of boards were manufactured from pine *(Pinus sylvestris*) chips and resinated with pMDI in the core and with MUPF resin in face layers. An enhanced load-bearing capacity of OSB/4 as a rule results from the application of higher resination rates in their manufacture. The basic properties of the tested boards are presented in Tab. 1. All tested boards, irrespective of their type or thickness, exhibited a similar value of swelling in thickness after 24 h soaking in water. Moreover, all the tested boards were characterised by considerable internal bond and bending strength. In turn, while OSB/4 of 8 mm in thickness exhibits an over 2-fold higher moisture resistance, measured by the V100 tests, than required by the standard EN 300 (0.17 N/mm^2), already OSB/4 of 22mm does not meet the requirements of this standard (0.13 N/mm^2). Moreover, OSB/3 is characterised by a considerable moisture resistance, even higher than that of OSB/4 with identical thickness.

In order to determine the effect of drying temperature on changes in board properties it was decided to run tests of internal bond with soaked and later dried samples (drying was conducted at different temperatures – see below). For this purpose, a total of 160 samples of 50 x 50 mm^2 were prepared from 15mm OSB/4, and they were soaked in water at a temperature of 20 º ± 1 ºC. Soaking time of 46 h was considered sufficient to provide a high degree of saturation with water. After the soaking process, samples were divided into 8 sets, for which different variants of drying temperatures were adopted, i.e. 40 ºC, 60 ºC, 75 ºC, 90 ºC, 105 ºC, 130 ºC, 160 ºC and 200 ºC. After constant mass was reached and after cooling to ambient temperature, their internal bond was determined in accordance with the standard EN 319, which was adopted as an index of board structure damage.

To determine the effect of soaking time on the behaviour of the glue line in each type of the tested OSB, a total of 140 samples of 50x50 mm^2 were prepared. A point was marked (at diagonal crossing) on each

Table 1 Properties of tested commercial boards
Tablica 1. Obilježja komercijalnih ploča upotrijebljenih u eksperimentu

Property / *Obilježje*	**Thickness, mm** / *Debljina, mm*			
	OSB/4			OSB/3
	8	15	22	15
Density[a] ρ, kg/m^3 / *gustoća* ρ, *kg/m^3*	700[f] (40)	670 (40)	670 (25)	645 (30)
Swelling[b] G_t ,% / *bubrenje G_t ,%*	8.4 (0.9)	8.7 (0.9)	8.9 (1.1)	8.9 (1.1)
Modulus of rupture[c] MOR ǁ , N/mm^2 / *modul loma MOR* ǁ , *N/mm^2*	42.9 (7.2)	35.1 (5.4)	45.0 (2.82)	33.3 (4.65)
Modulus of rupture[c] MOR ⊥ , N/mm^2 / *modul loma MOR* ⊥ , *N/mm^2*	29.2 (1.6)	23.1 (1.9)	23.4 (1.36)	23.0 (2.33)
Modulus of elasticity[c] MOE ǁ , N/mm^2 *modul elastičnosti MOE* ǁ , *N/mm^2*	6150 (540)	5950 (500)	7820 (620)	5860 (470)
Modulus of elasticity[c] MOE ⊥ , N/mm^2 *modul elastičnosti MOE* ⊥ , *N/mm^2*	3580 (280)	3540 (220)	3710 (190)	3420 (240)
Internal bond[d] IB , N/mm^2 / *čvrstoća raslojavanja IB, N/mm^2*	1.11 (0.10)	0.84 (0.11)	0.78 (0.05)	0.65 (0.09)
V100[e] , N/mm^2	0.37 (0.03)	0.15 (0.01)	0.11 (0.01)	0.20 (0.01)

[a] according to EN 323; [b] according to EN 317; [c] according to EN 310; [d] according to EN 319; [e] according to EN 1087-1; [f] mean value, in parentheses standard deviation

sample, where sample thickness was measured every time. Thus prepared samples together with the control samples were then conditioned in a chamber at a constant temperature and humidity (20 ± 1 ºC and 30 % ± 5 % RH) for approx. 2 months. It was assumed that this period was sufficient for all the samples to reach identical moisture content at the entire cross-section. Dimensions and weight of each sample were measured and, using control samples, initial moisture content was determined. MC was determined using the gravimetric drier method for each type of boards; however, due to the statistically non-significant differences, moisture content of 5.80 % was assumed as a base moisture content for all board types. Conditioned samples were then soaked in water at 20 ±1 ºC for the period specified in the schedule (from 1 to 70 h). After the specified time, samples were gently dried using blotting paper and weighed, their thickness was measured to determine the dependence of swelling on absorbability. After this stage, the samples were again conditioned under identical conditions. Periodically weight of randomly selected samples was determined in order to establish their moisture content. The process was repeated until it could be assumed that all the samples reached the moisture content similar to the base one. The samples were then weighed, their thickness was measured and they were subjected to the internal bond test.

NTS was assumed to be the relative change in thickness (1):

$$NTS = \frac{t_x - t_0}{t_0} \tag{1}$$

where:

t_x – sample thickness after soaking and conditioning / *debljina uzorka nakon natapanja i kondicioniranja*,

t_0 – sample thickness before the soaking process / *debljina uzorka prije postupka natapanja*,

while a reduction of internal bond was defined as:

$$\Delta IB = \frac{IB_0 - IB_x}{IB_0} 100\ \% \tag{2}$$

where:

IB_0 – board strength before soaking / *čvrstoća raslojavanja prije natapanja*,

IB_x – board strength after soaking and conditioning / *čvrstoća raslojavanja nakon natapanja i kondicioniranja*.

Moreover, it was decided to approximate results of measurements using a 3rd order polynomial (3),

$$\begin{aligned}\hat{y} = b_0 + b_1x_1 + b_2x_2 + b_3x_1^2 + b_4x_2^2 + b_5x_1x_2 \\ + b_6x_1^3 + b_7x_2^3 + b_8x_1^2x_2 + b_9x_1x_2^2\end{aligned} \tag{3}$$

applying an acknowledged technique of response surface methodology (RMS) (Box and Draper, 2007). Polynomial coefficients were determined using the least square method.

Board thickness in the adopted polynomial, i.e. 8, 15 and 22 mm, was decided to be the first independent variable ζ_1, while the second independent variable ζ_2 was assumed to be the time of board soaking in water, i.e. 0, 1, 2, 4, 6, 10, 14, 18, 22, 30, 38, 46, 54, 62 and 70 h However, in order to develop a model variable ζ_1 was reduced to x_1 according to equation (4) and ζ_2 to x_2 according to equation (5):

$$x_1 = (\xi_1 - 15)/7 \tag{4}$$

$$x_2 = \xi_2 / 70 \tag{5}$$

The degree of fit of the model to empirical data is presented in Fig. 1. It results from the presented data that the assumed model showed a very high degree of fit, since for all the analysed dependencies its R^2 value was greater than 0.98.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Internal bond of boards soaked in water for 46 h and then dried at different temperatures is presented in Fig. 2.

It may be concluded from the presented data that the range of occurring changes may be described by two equations of regression curves, characterized by high values of fit indexes R^2. The first of them describes changes occurring in the glue line in the temperature range of 40 – 90 ºC, and the other in the range of 105

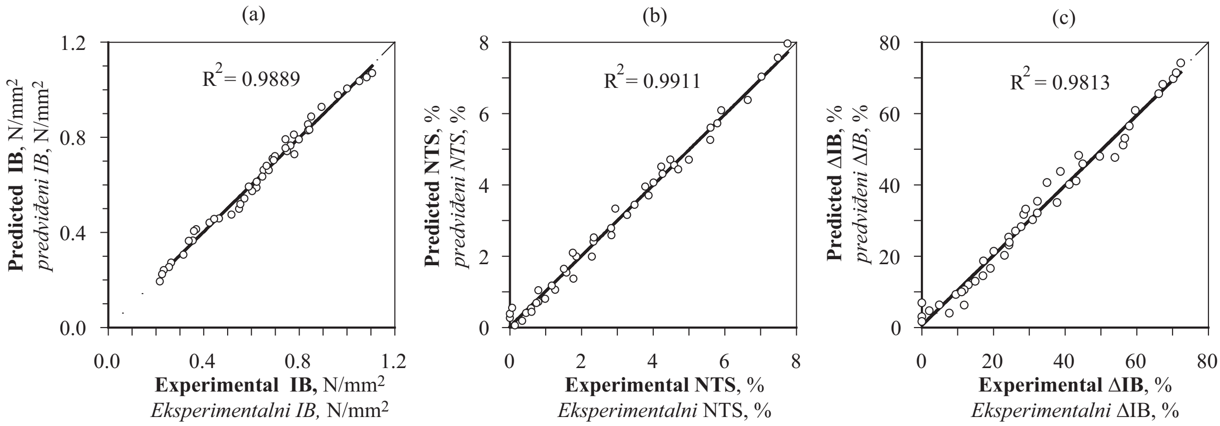

Figure 1 Experimental vs. predicted responses of the models as compared with ideal responses
Slika 1. Korelacija između eksperimentalnih i modelom predviđenih vrijednosti trajne promjene debljine ploča

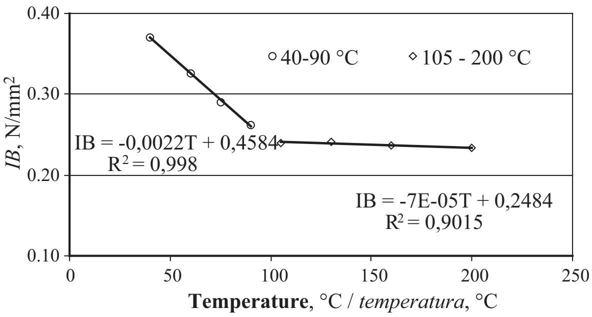

Figure 2 The effect of drying temperature of OSB/4 soaked for 48 h in cold water on internal bond
Slika 2. Utjecaj temperature sušenja na čvrstoću raslojavanja OSB/4 ploča nakon 48-satnog natapanja u hladnoj vodi

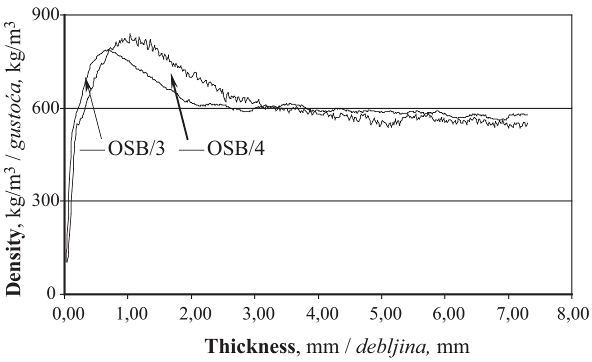

Figure 3 The density profile of tested commercial boards of 15 mm in thickness
Slika 3. Profil gustoće komercijalnih ploča debljine 15 mm upotrijebljenih u istraživanju

– 200 ºC. In the range of 40 – 90 ºC, we may observe an intensive drop in internal bond, while over 105 ºC these changes are much milder. For presented dependencies, a common point for both straight lines is approx. 100 ºC. Thus, it results from the presented dependencies that after exceeding the temperature of 100 ºC, no significant changes are observed in properties of OSB, this being a consequence of an additional factor, i.e. drying temperature. Thus a well-known regularity is confirmed that the milder are the conditions causing changes (reduction) of moisture content in wood or wood-based materials, the smaller is the degradation of their mechanical properties.

The dependence of swelling on absorbability is presented in the form of a linear regression equation $TS = a_0 + a_1WA$, giving in Table 2 the values of coefficients for this equations as well as the fit index r^2. Table 2 also presents the values of absorbability and swelling recorded for tested boards after 70 h soaking in water.

As it could have been expected, there is a highly linear dependence of swelling in thickness and the amount of water absorbed by OSB. Such an assumption was presented not only by Wu and Piao (1999), but also by Mirski *et al.* (2011). Although it does not reflect the actual course of sorption and its effect in the form of linear expansion, it still seems to sufficiently well describe the occurring changes.

Moreover, as it results from the data presented in Tab. 2, the greatest increment in thickness, caused by the absorption of an identical amount of water, was found for OSB/4 of 8 mm in thickness, while it was the lowest in 2 mm OSB/4. In turn, 15 mm OSB/3 has a

Table 2 Regression results on TS-WA relationship for OSB/3 with a linear model ($TS = a_0 + a_{1.}WA$)
Tablica 2. Rezultati regresijske analize linearne povezanosti bubrenja i apsorpcije vode ploče OSB/3 ($TS = a_0 + a_{1.}WA$)

Regression coefficients *Koeficijent regresije*	**Unit** *Jedinica*	**Numerical value** / *Numerička vrijednost*			
		Board thickness, mm / *Debljina ploče, mm*			
		8	15	22	15
		OSB/4			OSB/3
a_0	%	-0.7505	-1.8564	-2.6324	- 2.5370
Slope, a_1	%/%	0.3855	0.3532	0.3229	0.3333
R^2	-	0.9954	0.9926	0.9884	0.9939
TS	%	14.00	19.44	15.43	21.74
WA	%	39.23	60.57	54.88	71.64

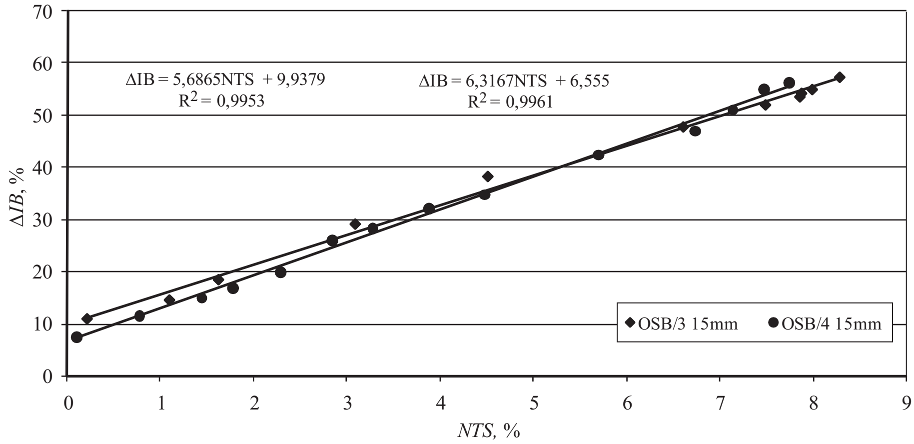

Figure 4 Reduction of internal bond in OSB/3 and OSB/4 boards depending on the residual deformations
Slika 4. Smanjenje čvrstoće raslojavanja ploča OSB/3 I OSB/4 u ovisnosti o trajnoj promjeni njihove debljine

similar coefficient of changes in thickness as 22 mm OSB/4. Such behaviour of boards confirms earlier reports that the swelling ratio in OSB is related to their density (Rice and Carey, 1978; Mirski *et al*. 2011).

As it could have been expected, the greatest swelling in thickness after 70 h soaking was found for OSB/3. The swelling value for this board is 21.74 %, but it is still by only 2.5 % higher than swelling in OSB/4 of identical thickness. It seems that swelling of 15 mm OSB/4 is relatively high both in relation to OSB/3 and the other OSB/4 variants. While the observed high swelling in OSB/3 may be explained by a lower resination ratio at the manufacture of such boards, high swelling in OSB/4 of identical thickness comes as a surprise. However, it results from the data presented in Tab. 1 that physical and mechanical properties of these boards are practically identical, except for internal bond and strength after the boiling test. Higher IB values for OSB/4 may probably be attributed to the higher average density and the distribution of density at the board cross-section. As it results from Fig. 3, in case of this board there is a greater density of chips in the face layer.

Extension of the zone of lower densities in OSB/3 also results in a markedly higher absorbability. In turn, the recorded high strength of OSB/3 after the boiling test causes a situation when at such a long soaking time the effects of density and moisture resistance begin to be balanced. The above statement is also confirmed by the fact that a reduction of internal bond, which may be described with a good approximation with a linear equation in the function of residual deformations for both boards, is very similar (Fig. 4).

Values of residual deformations observed for OSB/4 are presented in Fig. 5.

It results from these data that short-term soaking, of max. 5 h, causes only slight non-recoverable thickness swelling, of only 1 %, in OSB/4, and it is irrespective of their thickness. With the time of board exposure to cold water, the volume of thickness swelling increases and, in the analyzed case, it starts to depend more markedly on board thickness. Up to 24 h these differences are still slight, but with an extension of soaking time, it becomes evident that the greatest non-recoverable deformations are found in 15 mm boards. High resistance of 8 mm boards is probably a consequence of both high density and the stated moisture resistance determined by the boiling test (Table 1). Such a situation is also indicated by low absorbability of these boards, determined after 70 h soaking in cold water. In turn, 22 mm OSB/4, despite its much lower density, potentially suggesting higher capacity to absorb water, and a relatively low moisture resistance, possibly reflected in the values of swelling, exhibits both low values of non-recoverable deformations and swelling (Table 2). The low swelling ratio and low values of non-recoverable deformations indicate that the tested board is characterized by a high level of chip hydrophobicity. Such an effect may be obtained by an increase in the amount of hydrophobic additives and/or thanks to the application of higher resination rates. It is a well-known fact that commonly used paraffin emulsions effectively reduce the hydrophilic character of

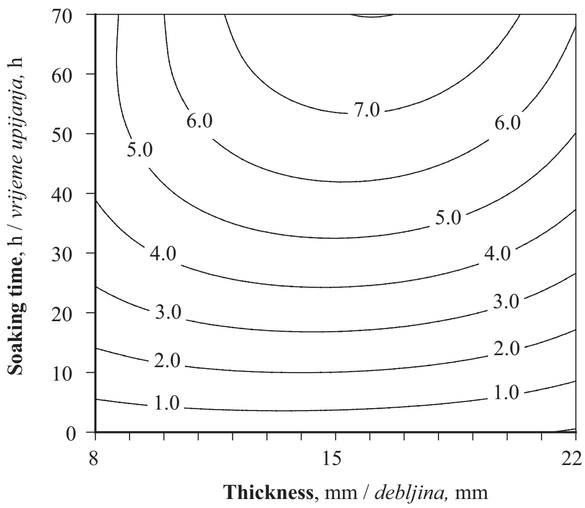

Figure 5 Expected residual deformations after drying depending on soaking time and thickness of OSB/4
Slika 5. Očekivane vrijednosti trajne promjene debljine ploča nakon sušenja u ovisnosti o vremenu natapanja i debljini ploča

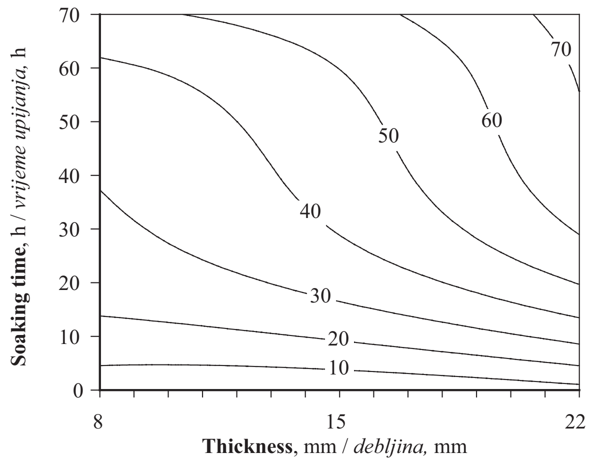

Figure 6 Expected relative reduction of internal bond depending on soaking time and thickness of OSB/4
Slika 6. Očekivane vrijednosti smanjenja čvrstoće raslojavanja u ovisnosti o vremenu natapanja i debljini ploča

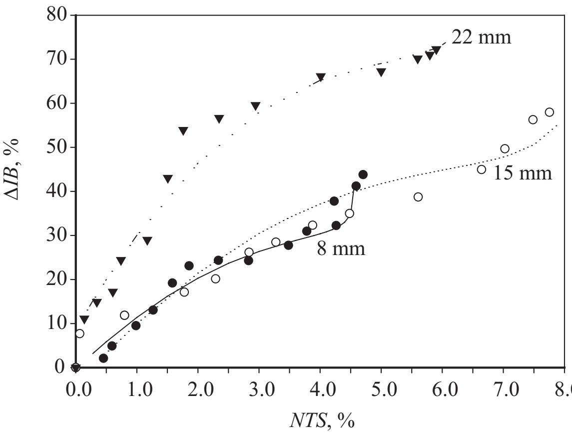

Figure 7 Dependence between residual deformation of OSB/4 with various thicknesses and permanent deterioration of internal bond
Slika 7. Ovisnost trajne promjene čvrstoće raslojavanja i trajne promjene debljine ploče za ploče različitih debljina

materials during their exposure to cold water, whereas in hot water they are dissolved.

The effect of soaking time of OSB/4 on their internal bond is presented in Fig. 6.

As it results from the provided data, in case of a short-term soaking of boards, irrespective of their thickness, we may observe a permanent reduction of internal bond, amounting to 10 - 20 %. With an extension of soaking time the degree of degradation increases, and it is much greater for thicker boards. During IB strength testing, most samples were destroyed in the core and it was irrespective of board thickness. Only in several cases, rupture occurred at the interface of the core and the face layers. Thus in the scheduled testing period, even if the observed linear expansion pertained mainly to face layers, potentially suggesting that the greatest degradation of the glue line took place in those layers, the core was still the weakest point in terms of its internal bond. In the opinion of the authors of this study, the markedly lower density of the core in OSB results in a situation where penetration of water is faster in this layer and hence stresses are first formed there, causing glue line degradation. Although linear expansion (swelling) in this layer is not as marked as in the face layers, as suggested in the study by Wang and Winistorfer (2003), it seems that the observed reduction of strength and at the same time degradation of the glue line are mostly related to the core. Obviously, we may not reject a hypothesis that the percentages of destruction changes in face layers are greater. However, their high initial strength results in a situation where for the adopted testing period the core still remains the weakest part of the board. In this respect suggestions of the authors seem to confirm the results of a still unpublished paper, from which it results that a significant reduction of strength in the face layers of OSB occurs only after 4 - 5 cycles of the V313 test.

The relationship between residual deformation in OSB/4 of various thicknesses and a permanent reduction of internal bond is presented in Fig. 7.

As it results from these data, the constructed mathematical model based on equation (3) illustrates well the process of changes occurring in tested boards. Only in case of 15 mm boards, the character of occurring changes may be described by a linear equation, as presented in Fig. 4. It results from this model that for each board thickness there is a certain boundary value of residual deformation, which, when exceeded, results in a dramatic decrease of strength. Thus, for example, in case of 8 mm boards, this effect may be observed after exceeding 4 % NTS, while in 15mm boards it may be observed after exceeding approx. 7 %. Such behavior of boards may be expected, since long-term board soaking causes their destruction exceeding the capacity of boards to return to the original thickness.

4 CONCLUSION
4. ZAKLJUČAK

As a result of tests conducted, it was found that the conditions, under which previously soaked boards are dried, have a significant effect on their residual strength. As it could have been expected, the milder the board drying conditions (lower temperature, higher humidity), the smaller their reduction of strength. The boundary temperature, after which such a significant deterioration of strength is no longer observed, is the boiling point of water. However, at this temperature, the strength of boards is already by over 40 % lower than that found after drying at 40 ºC.

Moreover, it results from the tests conducted that the soaking time significantly influences the strength of OSB in terms of their internal bond. However, short-term soaking up to approx. 5 h causes a permanent reduction of strength by only approx. 10 – 20 %, and this is irrespective of board thickness. In turn, a longer soaking time results in a situation where the internal bond is reduced to a greater extent in thicker boards. Thus, the observed decrease in strength after 60 h soaking in case of 8 mm boards was approx. 45 %, while for 22 mm boards it exceeded 70 %.

The formed permanent residual deformations, whose volume is strongly connected with the soaking time and drying temperature, within a certain range may be connected linearly with a decrease in internal bond. Except for 15 mm boards, this pertains mainly to very small values of residual deformations, typically below 2 %. However, irrespective of OSB thickness there is a boundary value of NTS, where a significant deterioration of strength is observed.

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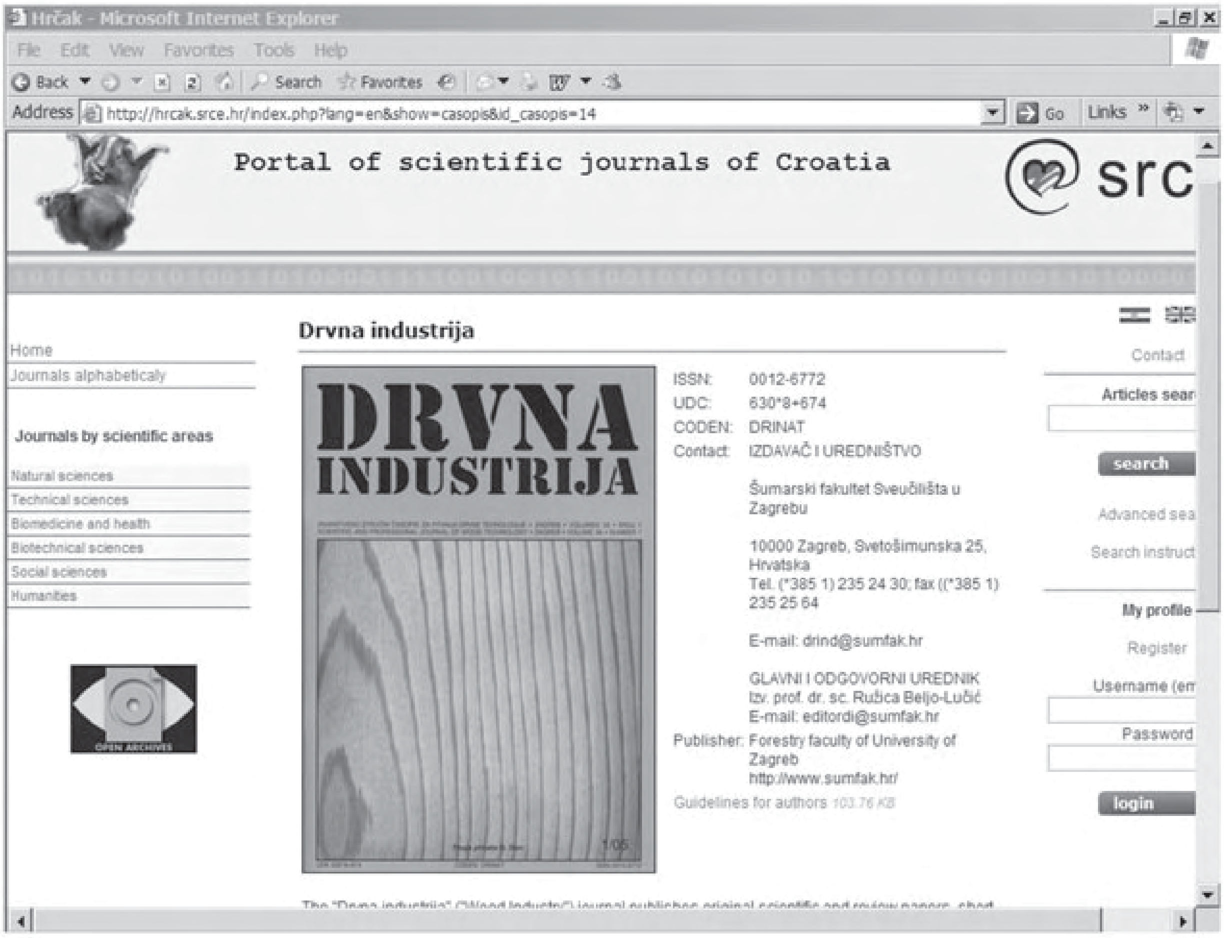

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Choice of Quantitative Method for Forecasting of Parquet Sales

Izbor kvantitativne metode za predviđanje prodaje parketa

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ABSTRACT • *Companies that cannot predict business forecasts for their sales always find themselves in ambiguity. In this research we analyzed two quantitative methods that gave the best results for forecasting the sales: Holt-Winters method of exponent smoothing of higher orders and linear regression of the 1st order. The data for the implementation of these two methods were obtained in a wood company that deals with parquet sales. The data were gathered for parquet sales by month in the years 2000 to 2009. The calculations of sales forecasts enabled to compare both methods. On the basis of smaller deviations from data obtained, we determined the most appropriate method. We received the best result with the use of Holt-Winters multiplicative model of exponent smoothing of higher orders. Thus, according to this research, this method should be used for further forecasting of parquet sales in the analyzed wood company.*

Key words: *wood company, parquet, sales forecasting, quantitative methods, Holt-Winters multiplicative model*

SAŽETAK • *Poduzeća koja ne mogu predvidjeti prodaju svojih proizvoda posluju u neizvjesnosti. U ovom smo istraživanju analizirali dvije kvantitativne metode koje daju najbolje rezultate u predviđanju prodaje: Holt-Wintersovu metodu eksponencijalnog izglađivanja viših redova i jednostruku linearnu regresiju. U poduzeću koje se bavi prodajom parketa radi predviđanja buduće prodaje prikupljeni su podaci o mjesečnoj prodaji u razdoblju od 2000. do 2009. godine. Na temelju izračunatih predviđenih vrijednosti prodaje omogućena je usporedba primijenjenih metoda. Ovisno o manjim odstupanjima od realiziranih vrijednosti izabrana je prikladnija metoda. Primijenom Holt-Wintersova multiplikativnog modela eksponencijalnog izglađivanja viših redova dobiveni su bolji rezultati, te bi ta metoda trebala biti rabljena za predviđanje prodaje parketa u analiziranome drvnom poduzeću.*

Ključne riječi: *drvno poduzeće, parket, predviđanje prodaje, kvantitativne metode, Holt-Wintersov multiplikativni model*

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1 INTRODUCTION
1. UVOD

In the business world, companies constantly face uncertainty. It was a big challenge for the companies to reduce these uncertainties and ambiguity by good sales forecasting. On the basis of good future planning, a company can develop an appropriate strategy, according to which business should be performed in the future (Anderson *et al*, 2010).

Due to the existence of many factors that may influence the sales, each company has its own characteristics regarding forecasting. In forecasting, qualitative or quantitative methods are used as well as the combination of these two methods. The decision as to what method to use depends on the available data, knowledge and experience of the decision maker (Ljubič, 2006).

Our research includes two quantitative methods for forecasting: Holt-Winters method of exponent smoothing of higher orders and linear regression of the 1st order. They are both based on past numeric data. Using these two methods, we attempted to get as close as possible to the values of parquet sales obtained in the selected wood company given by month in the years 2000 to 2009. We compared the results of both methods. Consistent with the results of short-term forecasts, the most appropriate method was established. We believe that the use of the method selected in such a way could enable accurate forecasts of parquet sales in the investigated/selected company in the years to come.

2 METHODS AND MATERIALS
2. METODE I MATERIJALI

2.1 Forecasting
2.1. Predviđanje

Methods of forecasting have started to develop with acceleration in the 19th century, nevertheless their use in practice increased with the arrival of computers (Bowerman and O'Connell, 1993). The main problem was that such methods needed to perform many complicated and time consuming mathematical operations. Nowadays, the use of forecasting procedures is simplified. There are many computer programs available to predict the development of future business events, as for example the forecasting of the sales.

For forecasting any kind of events, the researcher has to acquire certain knowledge, because, if he/she uses data that are not the key data of the forecasting problem, or not appropriate for the used prediction model/method, the outcome of the model will be definitely wrong. The researcher also has to be able to correctly interpret the forecast from the obtained results, as numbers and diagrams do not disclose everything. It is practically impossible for a certain event to be forecasted accurately by the use of the forecasting method. Forecasting methods are only a decision support tool and only help to reduce the error or difference between a forecasted event and an actual event (Bovas and Ledolter, 2005).

2.2 Quantitative methods
2.2. Kvantitativne metode

Quantitative models are based on mathematical and statistical methods. For such models, numerical data from the past are needed/used. For calculating parquet sales forecasts in the wood company, we decided to use two methods that gave the best results regarding the actual/obtained data: Holt-Winters method of exponent smoothing of higher orders and linear regression of the 1st order.

2.2.1 Holt-Winters multiplicative model
2.2.1. Holt-Wintersov multiplikativni model

Multiplicative model assumes that the sales decrease or increase each year for a given factor, or that the basic value is multiplied by the seasonal factor (Kotsialos *et al*., 2005). If the factor is more than 1, the sales increase, if it is less than 1, the sales decrease. This method uses smoothing with uneven seasonal oscillation (Mole, 2011).

The basic equations for Holt-Winters multiplicative method are as follows (Makridakis *et al*., 1998):

$$\text{Level:} \quad L_t = \alpha \cdot \frac{Y_t}{S_{t-s}} + (1-\alpha) \cdot (L_{t-1} + b_{t-1}) \tag{1}$$

$$\text{Trend:} \quad b_t = \beta \cdot (L_t + L_{t-1}) + (1-\beta) \cdot b_{t-1} \tag{2}$$

$$\text{Seasonal:} \quad S_t = \gamma \cdot (\frac{Y_t}{L_t}) + (1-\gamma) \cdot S_{t-s} \tag{3}$$

$$\text{Forecast:} \quad F_{t+m} = (L_t + b_t\, m) \cdot S_{t-s+m} \tag{4}$$

where *s* is the length of seasonality (e.g., number of months in the year), L_t represents the level of the series, b_t denotes the trend, S_t is the seasonal component, and F_{t+m} is the forecast for *m* periods ahead.

Equation (3) is comparable to a seasonal index that is found as a ratio of the current values of the series, Y_t, divided by the current single smoothed value for the series, L_t. If Y_t is larger than L_t, the ratio will be greater than 1, while if it is smaller than L_t, the ratio will be less than 1. To understand this method, it is important to realize that L_t is a smoothed (average) value of the series that does not include seasonality (this is the equivalent of saying that the data have been seasonally adjusted). The data values Y_t, on the other hand, do contain seasonality. It must also be considered that Y_t includes randomness. In order to smooth this uncertainty, equation (3) weights the newly computed seasonal factor with γ and the most recent seasonal number corresponding to the same season with (1-γ). This prior seasonal factor was computed in the period $t-s$, since *s* is the length of seasonality (Mole, 2011).

2.2.2 Linear regression of the 1st order
2.2.2. Jednostruka linearna regresija

Linear regression of the 1st order is the simplest and very commonly used method in forecasting. It is used for long-term forecasting of sales or demand, forecasting of storage stocks and similar. It is employed if linear regression function is considered, and namely:

$$Y = a + bX + e \tag{5}$$

where *X* is the independent variable, *Y* is the dependent variable, *a* is the intercept, *b* is the slope of the line

Table 1 Sales of different types of parquet in the selected company from 2000 to 2009 (in m²)
Tablica 1. Prodaja različitih tipova parketa u promatranom poduzeću od 2000. do 2009. (u m²)

Parquet *Parket*	**Classic** *Klasični*	**Lamellate** *Laminat*	**Techno** *Tehno*	**Lam** *Lamel*	**Ready made** *Mozaik*	**Terrace** *Brodski pod*	**Sum** *Zbroj*
2000	16,360.18	19,042.29	0.00	5,271.44	962.52	0.00	41,636.43
2001	14,090.67	30,975.19	240.00	5,328.24	1,933.12	0.00	52,567.22
2002	20,486.88	22,189.91	0.00	5,342.20	1,978.10	0.00	49,997.08
2003	16,556.99	16,871.25	268.34	4,105.91	2,253.45	0.00	40,055.94
2004	12,391.97	13,800.34	1,547.97	2,144.14	1,903.15	24.50	31,812.07
2005	15,699.13	9,588.45	1,052.73	2,917.90	4,250.60	134.01	33,642.81
2006	16,334.66	5,861.84	1,041.57	1,829.52	6,892.76	274.79	32,235.14
2007	17,517.67	12,496.05	2,273.05	1,801.95	6,760.53	3,978.33	44,827.59
2008	11,643.23	5,166.51	3,179.49	1,590.12	8,230.08	877.90	30,687.34
2009	14,513.39	3,358.48	652.43	810.14	10,408.53	1,214.06	30,957.02
Sum / *Zbroj*	155,594.77	139,350.31	10,255.58	31,141.56	45,572.84	6,503.59	388,418.65

(how much Y changes for each one-unit change in X), and e denotes the error (the deviation of the observation from the linear relationship).

The objective is to find the values a and b. The linear function $Y=a+bX$ presents the »best fit« to the given data. The main goal of the linear regression is to fit a straight line through the data that predict Y based on X. To estimate the intercept and slope regression parameters that determine this line, the least square method is commonly used. It is not necessary for the errors to have a normal distribution, although the regression analysis is more efficient with this assumption. With this regression method, the regression parameters are found such that the sum of squared residuals (i.e., the difference between the observed values of the outcome variable and the fitted values) is minimized. The fitted value y is then computed as a function of the given x value and the estimated intercept and slope regression parameter. For example, in Equation (5), once the estimates for a and b are obtained from the regression analysis, the predicted value y at any given x value is calculated as $a + bx$.

It is meaningful to interpret the coefficient of determination, i.e., the value r^2. It is in the range of 0 to 1 and measures the portion of the variability in Y that can be explained by the variability in X through their linear relationship, or vice versa:

$$r^2 = \frac{SS_{\text{regression}}}{SS_{\text{total}}} \quad (6)$$

where SS stands for the sum of squares.

This method is subject to several disadvantages sourcing from input data and the question of linearity or non-linearity the trend function presenting the investigated phenomenon.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Parquet sales data in the considered wood company
3.1. Podaci o prodaji parketa u promatranome drvnom poduzeću

The wood company made available to us the parquet sales data by month from 2000 to 2009. On the basis of the obtained data and by the use of the appropriate forecasting method, we were able to deliver the short-term forecasts of parquet sales for the selected company. Table 1 presents the data on sales of different types of parquet in the selected wood company from 2000 to 2009.

The company was the most successful in 2001, when they sold over 52,560 m² of parquet. They reached the lowest level of sales in 2008, when they sold only 30,687.34 m² of parquet. Together, from 2000 to 2009, they sold more than 388,410 m² of parquet.

Figure 1 shows high sales in 2001, 2002 and 2007. In these years the company received an order to furnish big apartment complexes. The sales decreased in 2003 and 2004, and from then on the sales stood at more or less the same level. The major cause for lower

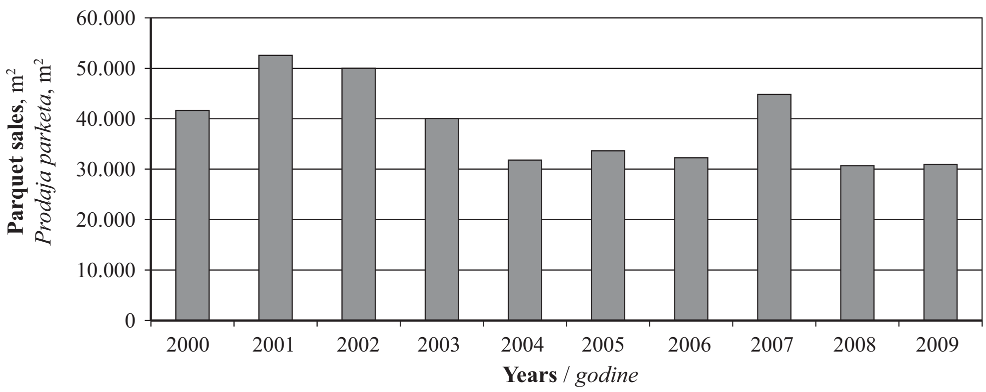

Figure 1 Sum of parquet sales in the invstigated company from 2000 to 2009
Slika 1. Ukupna prodaja parketa promatranog poduzeća od 2000. do 2009.

Table 2 Constants of basic value smoothing, trend and seasonal components used in calculating the parquet sales with Holt-Winters multiplicative model
Tablica 2. Primijenjene konstante temeljnih vrijednosti izglađivanja, trenda i sezonskih komponenata pri izračunu prodaje parketa Holt-Wintersovim multiplikativnim modelom

Forecasting method *Metoda predviđanja*	**Constants** / *Konstante*		
	basic value "α" *temeljna vrijednost* α	trend value "β" *trend vrijednost* β	seasonal component "γ" *sezonska komponenta* γ
Holt-Winters multiplicative model *Holt-Wintersov multiplikativni model*	0.22	0.035	0.01

sales in the years 2003-2006 is that in 2003 the company focused on sales of more expensive products and services of higher quality. The economic crisis in 2008 has certainly contributed to the decrease of sales in 2008 and 2009.

3.2 Parquet sales forecast with Holt-Winters multiplicative model
3.2. Prodaja parketa predviđena Holt-Wintersovim multiplikativnim modelom

In forecasting with Holt-Winters multiplicative model, the basic value for December 2000 was the average of all data in the year 2000. For the first trend value, the difference was calculated between the first and last data in 2000 and divided by 11.

Table 2 shows the smoothing constants used in the calculation with Holt-Winters multiplicative model. We calculated the values of constants with the help of "rescuer" in the program MS Excel. We entered the limits, i.e. the intervals [0.01; 0.99] in the rescuer. The program calculated the values of constants under the condition that the MAD (Mean Absolute Deviation) error was the smallest.

Table 2 shows that the values of constants are close to zero. This explains that the error and trend were considered as minimum. This can be clarified by the use of "older" data.

Table 3 shows that parquet sales were the lowest in January and the highest in October. In winter months, January and February, the sales were lower because of low temperatures, as it is difficult to guarantee appropriate climate conditions for drying screeds and parquet installation in the winter. At the end of the year, even at low outside temperatures, the sales were higher. The explanation for so high values lies in the fact that the companies invest profit into material to reduce taxes.

Table 4 shows the data of Holt-Winters multiplicative model for forecasting the sales of the selected wood company. The value of MAPE (Mean Absolute Percentage Error) and MAD are very low. TS (Tracking Signal) is a tracking signal used for monitoring forecasting through a longer period and for determining the forecasting accuracy compared to the actual values. It should be emphasized that through this method the trend represents a disturbing factor in forecasting sales.

3.3 Forecasting sales with Linear Regression of the 1st order
3.3. Prodaja predviđena modelom jednostruke regresije

It turned out that the original data that we used for the calculation with the linear regression of the 1st order had a seasonal character. Thus, we corrected the final forecast by a seasonal index, which was calculated by the use of Holt-Winters multiplicative model.

For the calculation, we used MS Excel and its function LINEST. We computed two parameters that describe the linear function, i. e., the regression constant, *a,* and regression coefficient, *b*. The value of the determination coefficient and its square root the coefficient of regression were calculated as well.

3.4 Comparison of results
3.4. Usporedba rezultata

The results for forecasting of parquet sales with linear regression of the 1st order, corrected with the seasonal component and multiplicative Holt-Winters model of exponent smoothing of higher order are shown in Figure 2.

Tables 4 and 5 and Figure 2 show that the MAPE and MAD errors are lower with Holt-Winters multiplicative model than with linear regression of the 1st or-

Table 3 Values of multiplicative seasonal components (MSC)
Tablica 3. Vrijednosti multiplikativnih sezonskih komponenata (MSK)

Month *Mjesec*	**January** *Siječanj*	**February** *Veljača*	**March** *Ožujak*	**April** *Travanj*	**May** *Svibanj*	**June** *Lipanj*	**July** *Srpanj*	**August** *Kolovoz*	**September** *Rujan*	**October** *Listopad*	**November** *Studeni*	**December** *Prosinac*
MSC *MSK*	0.67	0.70	0.95	0.94	0.79	1.14	1.13	1.09	1.08	1.30	1.05	1.13

Table 4 Calculation of sales forecasts with Holt-Winters multiplicative model
Tablica 4. Izračun predviđene prodaje primjenom Holt-Wintersova multiplikativnog modela

Forecasting method / *Metoda predviđanja*	**MAPE**	**MAD**	**TS max**	**TS min**
Holt-Winters multiplicative model / *Holt-Wintersov multiplikativni model*	26.8	758.8	29.9	1.0

MAPE error (Mean Absolute Percentage Error / *srednja apsolutna postotna greška*); MAD (Mean Absolute Deviation / *srednja apsolutna devijacija*); TS max (Tracking Signal Maximum/ *maksimalni signal*); TS min (Tracking Signal Minimum/ *minimalni signal*)

Table 5 Calculation of sales forecast with linear regression of the 1st order
Tablica 5. Izračun predviđene prodaje primjenom modela jednostruke linearne regresije

Forecasting method *Metoda predviđanja*	**MAPE**	**MAD**	**TS max**	**TS min**	**Function** *Funkcija*
Linearn regression of 1th order *Jednostruka linearna regresija*	29.0	780.5	22.3	1.0	$y = 3717.486\text{-}8.430 \cdot x$

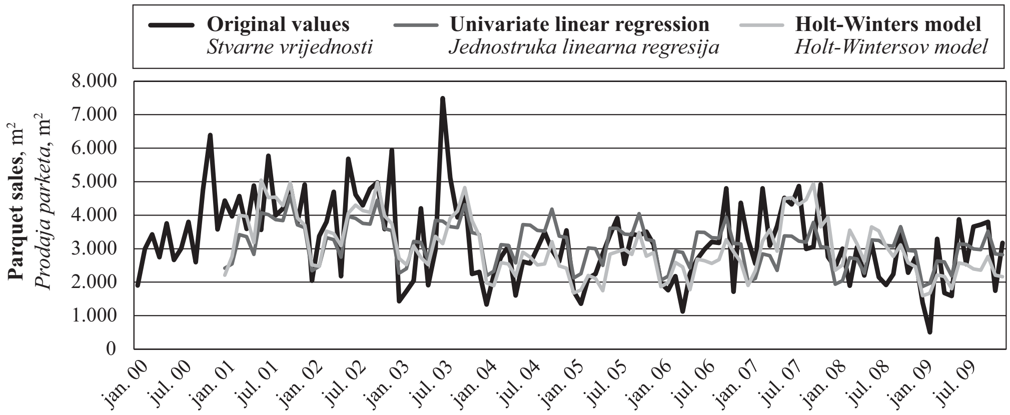

Figure 2: Parquet sales forecasts with linear regression of the 1st order, corrected with the seasonal component and multiplicative Holt-Winters model of exponent smoothing of higher order.
Slika 2. Prodaja parketa predviđena jednostrukom linearnom regresijom uz korigirane sezonske komponente i multiplikativnim Holt-Wintersovim modelom eksponencijalnog izglađivanja viših redova

der, but for the latter the tracking signal TS shows that the forecasted sales values are more appropriate than with Holt-Winters multiplicative model.

3.5 Selection of the most appropriate model
3.5. Izbor najprikladnijeg modela

According to the calculations performed, we selected the method which could be reasonably used for short term forecasting of parquet sales in the investigated wood company. We set the criteria that the method should fulfill for this selection. The chosen criteria were:

- Reliability or accuracy – MAD and MAPE errors and tracking signal TS;
- Understandability – an inexperienced person can quickly understand what a method demands and represents;
- Scope of forecast calculations – the time that a person without experience needs to perform forecasts;
- Updating – how will the method or forecast work if updated with more recent data;
- Adapting – is regular adaptation of forecasting possible;

Accuracy is the most important criterion for evaluating the forecasting method. In our case, the Holt-Winters multiplicative model is better regarding the accuracy criteria because MAD and MAPE errors are small. On the other hand, it should be said that this method yields quite a high value of the tracking signal TS, which means that the forecasts of parquet sales were too low. As the linear regression of the 1st order generated higher values of MAD and MAPE errors, according to the criterion of accuracy, Holt-Winters multiplicative model proved to be better.

Regarding the criterion of understandability, the linear regression of the 1st order is more appropriate, because linear regression in commonly known and widely used. To understand the Holt-Winters multiplicative model, the researcher has to master the theory.

The size of calculation is smaller with linear regression of the 1st order, because it simply captures the data and statistical computer program calculates and draws the forecast figures. With Holt-Winters multiplicative model the procedure of calculation is much more complicated.

Updating of models is important and in some cases a very complicated procedure. Updating should be simple, i.e., entering new data in the model should rapidly update the forecast for the next period. With linear regression of the 1st order, we have to enter new data and then again calculate the optimal values of all coefficients. With Holt-Winters multiplicative model we have to enter data and then again calculate the forecast function. Here, both models are equally suitable, because both need some additional work for updating the forecasts.

Model adaptation followed by forecast adaptation is desirable. Adaptations are only possible with Holt-Winters multiplicative model, because this method has three coefficients available that enable the adaptation of the forecast. With linear regression of the 1st order, the adaptation of the forecast is not possible, because the forecast is in the form of a function that depends on the data obtained and in our case on the seasonal component.

Taking into account all the findings regarding the criteria for the selection of the appropriate forecasting method, Holt-Winters multiplicative model is more appropriate. Although we need some time to master this method, it is a more sophisticated choice. Thus, using the Holt-Winters multiplicative model, the investigated wood company could obtain the most appropriate short-term forecast of parquet sales.

4 CONCLUSION
4. ZAKLJUČAK

For any company, business forecasting has always been a very complex process. The company has to make at least a rough forecast to be able to decide how and in which direction it will do business in the future.

The investigated wood company deals with parquet sales. They made available to us the parquet sales data from 2000 to 2009, by individual months. The object of forecasting parquet sales was to select the forecasting method which provides the forecasts of sales that are as close as possible to the data achieved in the years 2000 to 2009.

The results of forecast calculations showed that among the two most often used methods for this kind of forecasting - Holt-Winters method of exponent smoothing of higher order and linear regression of the 1st order, corrected with seasonal component – the quantitative Holt-Winters method of exponent smoothing of higher order was more appropriate. Hence, we strongly recommended it for the use in forecasting of parquet sales in the investigated wood company.

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Bending Capacity of Middle Joints of Upholstered Furniture Frames

Moment savijanja T spojeva za ojastučeni namještaj

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ABSTRACT • *This study evaluates the edgewise bending moment capacity of the four most frequently used middle joints in the upholstered furniture frames. The research included the following joints: Mortise and Tenon, double Dowel, Corner Blocks and double Gusset Plates, designed in the form of middle joints and made of beech and poplar solid wood. The test results indicated that regarding the edgewise bending force, the strongest middle joint was the double dowel joint made of beech wood (1896.9 N), while the respective joint made of poplar marked quite a low value of bending force (937.2 N). The strength of wooden corner blocks was proved to be quite powerful, made either of beech wood, poplar wood or the combination of the two wood species (beech: 1881.8 N, poplar: 1237.6 N, beech-poplar: 1783.6 N). The gusset plate joint made of beech resulted in weaker values (1378.2 N), compared to the dowel and corner block joints made of beech, whereas the same joint made of poplar demonstrated very satisfying values of edgewise bending force (1471.8 N). Finally, the mortise and tenon joint appeared to have the lowest strength, both in the case of beech (1306 N) and poplar (634 N). The highest coefficient of elasticity (CE) derived from double gusset plate joint, made of beech. All the joints showed good elasticity, except the mortise and tenon joint made of poplar, as well as, the dowel joint made of poplar, which recorded the lowest elasticity values of all. Generally, beech wood resulted in stronger and more elastic joints compared to poplar.*

Key words: *bending moment capacity, corner block joint, dowel joint, gusset plate joint, middle joint, mortise and tenon joint, upholstered furniture frame*

SAŽETAK • *U radu se prikazuje istraživanje momenta savijanja četiriju najčešće korištenih T sastava okvira ojastučenog namještaja. Istraživanje je obuhvatilo T spojeve okvira ojastučenog namještaja s čepom i rupom, dvostrukim moždanicima, drvenim kutnicima i dvostrukim drvenim pločicama. Uzorci su bili izrađeni od bukova i topolova drva. Rezultati ispitivanja pokazali su da je najjači spoj s obzirom na moment savijanja spoj okvira od bukovine s dvostrukim moždanicima (1896,9 N), dok je isti spoj od topolova drva imao prilično malu vrijednost momenta savijanja (937,2 N). Čvrstoća drvenog spoja izvedena drvenim kutnicima pokazala se vrlo dobrom bez obzira na to je li spoj izrađen od bukova ili topolova drva ili od kombinacije tih dviju vrste drva (bukovina: 1881,8 N, topolovina: 1237,6 N, kombinacija bukovina–topolovina: 1783,6 N). Spoj drvenim pločicama od bukovine pokazao je slabije vrijednosti (1378,2 N) od spoja dvostrukim moždanicima i spoja drvenim kutnicima od bukovine, dok je isti spoj od topolovine pokazao vrlo zadovoljavajuće vrijednosti momenta savijanja (1471,8 N). Konačno, spoj čepom i rupom pokazao je najslabije rezultate, kako u spoju od bukovine (1306 N), tako i u spoju od topolovine (634 N). Najviši koeficijent elastičnosti (CE) pokazao je spoj od bukovine s dvostrukim pločicama. Svi*

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spojevi rezultirali su sasvim zadovoljavajućim vrijednostima elastičnosti, osim spoja čepom i rupom od topolovine te spoja moždanicima od topolovine, koji je imao najniže vrijednosti elastičnosti od svih ispitivanih spojeva. Općenito, spojevi od bukovine pokazali su bolja svojstva čvrstoće i elastičnosti nego spojevi od topolovine.

Ključne riječi: *moment savijanja, spoj drvenim kutnicima, spoj moždanicima, spoj drvenim pločicama, spoj čepom i rupom, okvir ojastučenog namještaja*

1 INTRODUCTION
1. UVOD

The strength and stability of upholstered furniture mainly depend on the design of the frame pattern and the strength and stability of its joints (Eckelman 2003, Efe *et al*, 2005, Erdil *et al*, 2005 etc). Undoubtedly, there is a high interest in the research of the strength of the wooden frame and particularly the strength of the upholstered furniture joints.

The present research deals with the investigation of the edgewise bending moment capacity of the four basic and most frequently used middle joints of upholstered furniture, and namely: mortise and tenon joint, double dowel joint, wooden corner block joint and double gusset plate joint. The mortise and tenon joint and double dowel joint represent two main and traditional types of joints of upholstered and other sorts of furniture, and they have been already studied (Hill and Eckelman 1973, Paulenkova 1984, Smardzewski 2002, Tankut 2006, Zhang and Eckelman 1993, Efe *et al*, 2005), while the strength and the mechanical behavior of the other two types of joint presented in this research, the one with corner blocks and double gusset plates have not been thoroughly studied so far (Kazal et al. 2006, Erdil *et al,* 2003).

In this research, it was determined that the load was edgewise bending, because of the significance of the joint resistance to this type of load in the stability and resistance of the whole furniture frame. In the upholstered furniture, the middle joints are used to connect the front and back horizontal rails of the frame, a place where edgewise bending strength is the load that prevails and is therefore essential to test the joints with respect to this kind of load. The knowledge and understanding of the factors that affect the middle joint strength can be used in order to improve the joint design and hence the construction of the whole wooden frame of the furniture.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

Experiments were carried out with beech (*Fagus silvatica* L.) and poplar (*Populus sp.*), both of Greek origin and naturally dried for one year. The joints were constructed in the middle form (T-type) and their edgewise bending moment capacity was tested, and the corresponding coefficients of elasticity (CE) were also determined (in bending force). The specimens of double dowel and the mortise and tenon middle joints were only made of beech and poplar, while the other two joint types, the specimens of double corner block joint and double gusset plate joint¸ were not only made of beech and poplar, but also of a combination of the two wood species. Specifically, the third version of the double corner block joint was made of beech in the parts and poplar in the corner block joint of the specimens. Relatively to the double gusset plate joint, its third version was made of poplar in the parts and beech in the gusset plates of the specimen. The combination of these two wood species in corner blocks and gusset plates was to be tested because of its wide use (application) in the construction of upholstered furniture frames.

The dowels were made of beech wood, with the diameter of 12 mm and they had dapple surface. The adhesive used was Polyvinyl Acetate PVAc N203, durability class D3, with the density of 1.045 g/cm^3, pH 2.81, 46.8 % solid content after drying and viscosity of about 13,000 mPa·s at 20 ^{o}C and 65 % relative humidity. The staples were of Greek origin and construction, with the length of 4.5 cm for the connection of the two wooden elements and 3.5 cm for the assembly of corner blocks or gusset plates on the specimen.

All the specimens consisted of two horizontal wooden elements. The dimensions of the samples for testing the bending moment capacity were as follows: 150 mm length x 50 mm width x 25 mm thickness for element 1, while the dimensions for element 2 were 125 mm length x 50 mm width x 25 mm thickness. The specimens dimensions of the current research have been specified based on commonly used dimensions in the construction of furniture frames, because of lack of particular international standards on the research method of the middle joint strength.

Concerning the double dowel joint, the dimensions of the dowel were: 40 mm length x 12 mm in diameter and the space between the two dowels was 13 mm. In the construction of the mortise and tenon joint, the contact between the mortise and tenon was only to be maintained in the two surfaces of the mortise, because the mortise cut is semi-cylindrical, whereas the tenon has a square cut. In regard to the construction of the corner block joint, corner blocks with perpendicular sides of 30 mm were used. Also, each of the corner blocks was fixed by two staples. Regarding the construction of the double gusset plate joint, two wooden gusset plates were used alongside the connection place and each gusset plate was stabilized with the help of two staples (Figure1, D).

In the construction of the joints, pressure was not applied, except for those that included the use of staples (joint with corner blocks and joint with double gusset plates).

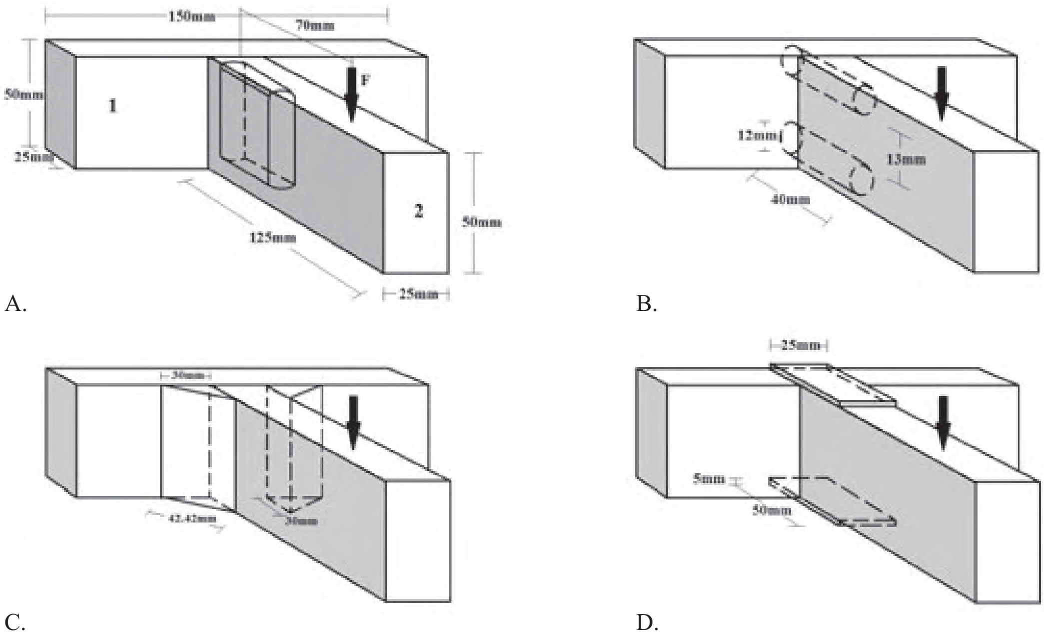

Figure 1 Configuration of specimens and the way of application of edgewise bending load: A. mortise and tenon joint, B. double dowel joint, C. corner blocks, D. double gusset plates
Slika 1. Oblik uzorka i smjer djelovanja sile opterećenja na savijanje: A. spoj čepom i rupom, B. dvostruki spoj moždanicima, C. spoj drvenim blokovima, D. spoj drvenim pločicama

For each joint, 10 specimens were tested. By using four types of joints, two wood species and a combination of the two species in two out of four joints, a total of 100 specimens were prepared. After their construction, the specimens were conditioned at the temperature of 20 °C and relative humidity of 65 % and they were left there for three weeks to reach the nominal equilibrium moisture content (EMC) of 10 %. At the moment of the tests, the mean density of beech was 0.702 g/cm^3 and of poplar 0.364 g/cm^3, while the mean moisture content was 9.55 % for beech and 9.29 % for poplar.

The test was carried out on a Universal Testing Machine (SHIMADZU UH-300kNA) and the rate of crosshead-movement was adjusted to 8 mm/min, so that the maximum load was reached within 1.5 ± 0.5 min throughout the test. The edgewise bending strength test of middle joints was performed using a specific device installed on the testing machine (Figure 2), in order to keep the element 1 of the specimen settled and leave the vertical part without support. The element 2 of the specimen was free to accept the pressure of the machine crosshead on its descent and the loading continued until the joint broke. At the end of this procedure, the maximum rupture load (N) in edgewise bending moment capacity of the middle joints was recorded.

After the measurements, the bending moment capacity (N·mm) and the coefficient of elasticity (CE) (N/mm^2) of the middle joints were calculated, using the following equations:

$$E = F \cdot S \tag{1}$$

where E is the bending moment capacity (N·mm), F is the maximum rupture load (N) and S is the moment arm (mm), which represents the distance measured

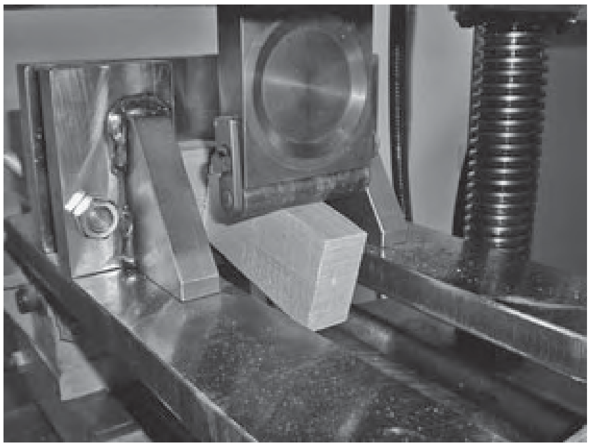

Figure 2 Device used for testing bending moment of middle joints
Slika 2. Uređaj za ispitivanje momenta savijanja drvenih spojeva

from the edge of element 2, till the point where the load is applied and in this research this length was 70 mm for all the specimens.

$$CE = \frac{L \cdot S}{A \cdot D} \tag{2}$$

where CE is the coefficient of elasticity (N/mm^2), L is the load at the elastic limit (N), S is the space between the two holding points of the joint (mm), A is the area of the transverse cut surface (mm^2) and D is the deformation at the elastic limit (mm).

For the statistical analysis of results, statistical software program SPSS PASW18 was used, and it was provided by the Aristotle University of Thessaloniki. Statistical analysis of covariance of the mean bending strength and elasticity values was carried out, using the Bonferoni and Tamhane method (one-way ANOVA).

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The aim of this research was to investigate the edgewise bending moment capacity of middle joints, mainly because of high interest caused by the significance of this type of load for the wooden frame strength of the upholstered furniture. Middle joints that connect the basic parts of a furniture frame receive a range of different loads that also interact with one another, while the dominant load is undoubtedly the edgewise bending.

According to the above table, regarding the edgewise bending moment capacity, the middle joint of double dowel, made of beech, excelled greatly compared to all the other joints of the research, with maximum rupture load of 1896.9 N (moment capacity: 132783.6 N·mm). A little lower values were measured in the corner block joint, made of beech (1881.8 N) (moment capacity: 131726 N·mm) and the same joint made of a combination of beech wood in the parts and poplar wood in the corner block 1783.6 N, (moment capacity 124852 N·mm).

The one that followed, regarding the edgewise bending force capacity, was the double gusset plate joint made of poplar with 1471.8 N (moment capacity: 103026 N·mm), while even lower strength values were given by the same joint made of beech, 1378.2 N (moment capacity: 96474 N·mm). This fact leads to the conclusion that this specific joint (double gusset plates) made of poplar exhibits satisfying strength, especially when the main load in the construction is the edgewise bending (upholstered furniture frame for example). In an attempt to interpret and explain this strength superiority of double gusset plates made of poplar, compared to the corresponding beech joint, one could claim that poplar wood, having a different level of wettability, potentially created a successful adhesion line, given that the glued surface (between the plates and the specimen wooden elements) is quite large in this kind of joints. A little lower value (1306 N) was given by the mortise and tenon joint, made of beech (moment capacity: 91420 N·mm) and the corner block joint made of poplar with 1237.6 N maximum rupture load (moment capacity: 86632 N·mm).

Lower edgewise bending force (942.4 N) was demonstrated by the double gusset plate joint, made of a combination of two different wood species (poplar in the parts and beech in gussets) (moment capacity: 65968 N·mm), while the strength value of the double dowel joint made of poplar ranged at the same level with 937.2 N (moment capacity: 65604 N·mm). Among all the joints, the mortise and tenon joint made of poplar wood with 634 N (moment capacity: 44380 N·mm) showed a very low bending force. The mortise and tenon joint is generally one of the most durable and stable joints, and it is recommended for use in constructions of solid wood. However in the case of this research, the double dowel joint seemed to be of much higher strength, while the mortise and tenon joint made of poplar showed the lowest strength of all the joints. This can be easily explained by the fact that the the mortise and tenon joint is designed in such a way that the tenon has a square cut, while the mortise has a semi-cylindrical cut, resulting in a reduced contact between the two wooden parts and a smaller gluing surface. Almost in all cases, with the exception of the double gusset plates, the joints made of poplar wood demonstrated much lower strength values compared to the respective joints made of beech wood and that is mainly attributed to the lower density of poplar wood. In a similar research, Efe *et al.* (2005) recorded a little higher edgewise bending force in the mortise and tenon as well as in double dowel middle joint, compared to the results of the present research, using three different wood species (beech, oak and pine), while Kazal *et al* (2006) found slightly lower edgewise bending strength in the corner block middle joint constructed with sweetgum and yellow-poplar wood.

According to the results of variance analysis, differences in groups were statistically significant with a

Table 1 Edgewise bending force and moment capacity of middle joints (mean values)
Tablica 1. Kapacitet sile i momenta savijanja drvenih spojeva

Joint type *Tip spoja*	**Wood species** *Vrsta drva*	**Maximum rupture load** *Najveće opterećenje* N	**Bending moment** *Moment savijanja* N·mm	**Stand. deviations** *Standardna devijacija*
Double dowel *dvostruki moždanici*	Beech / *bukovina*	1896.9	132783	7089.1
	Poplar / *topolovina*	937.2	65604	6510.3
Mortise and tenon *čep s rupom*	Beech / *bukovina*	1306.0	91420	7421.9
	Poplar / *topolovina*	634.0	44380	2055.1
Corner blocks *kutnici*	Beech / *bukovina*	1881.8	131726	8826.9
	Poplar / *topolovina*	1237.6	86632	8241.0
	Beech in the parts and Poplar in blocks *bukovina s topolovim kutnicima*	1783.6	124852	8628.1
Double gusset plates *dvostruke drvene pločice*	Beech / *bukovina*	1378.2	96474	7124.7
	Poplar / *topolovina*	1471.8	103026	6711.0
	Poplar in the parts and Beech in plates *topolovina s bukovim pločicama*	942.4	65968	6428.0

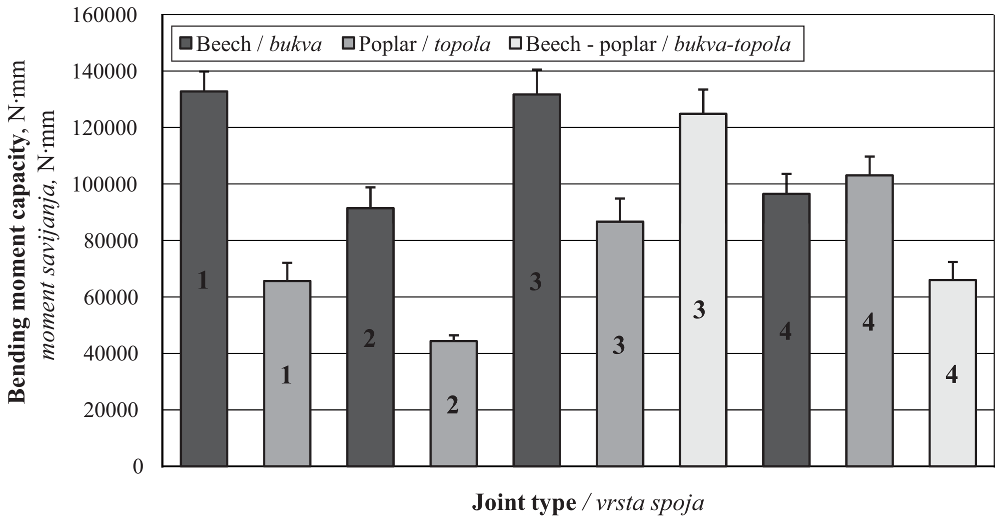

Figure 3 Edgewise bending moment capacity of middle joints: 1. Double dowel joint, 2. mortise and tenon joint, 3. corner blocks, 4. double gusset plates
Slika 3. Vrijednosti momenta savijanja drvenih spojeva: A. dvostruki spoj moždanicima, B. spoj čepom i rupom, C. spoj drvenim kutnicima, D. spoj drvenim pločicama

5% error. Statistically significant differences were recorded among all the joints, except for the following cases: double dowel joint made of beech wood gave similar values to the corner blocks made of beech wood and also to the corner blocks made of a combination of beech wood in the parts and poplar wood in the corner blocks. Furthermore, the strength value of the double dowel joint made of poplar wood did not differ significantly from the respective value of the gusset plate joint made of poplar in the parts and beech in plates. Additionally, similar values were determined for the mortise and tenon joint made of beech as well as for the corner blocks made of poplar wood, and the gusset plates, made either of beech or poplar wood. Also, similar strength seemed to have been obtained by the corner blocks made of poplar wood and the gusset plates made of beech wood. Finally, significant difference was not observed between the strength value of the gusset plates made of beech wood and the respective value of the same joint made of poplar wood.

The coefficient of elasticity (*CE*) of each joint is calculated through the relation of the load that acts on the joint, with the simultaneous deformation caused by it. According to the results, the highest *CE* values were measured in the double gusset plates made of beech (37.5 N/mm^2). The corner blocks made of a combination of beech in the parts and poplar in corner blocks followed with 33.2 N/mm^2 *CE* value, while a little lower *CE* value was recorded with the same joint made of beech wood (28.2 N/mm^2).

Lower coefficient of elasticity in edgewise bending force was measured in the mortise and tenon joint made of beech wood with *CE* value of 24.2 N/mm^2, and an even lower *CE* was measured in the corner blocks made of poplar wood (23.3 N/mm^2). The double dowel joint made of beech wood appeared to have a little lower *CE* value (22.7 N/mm^2). The elasticity value of the double gusset plates made of poplar was 21.2 N/mm^2, while the same joint made of a combination of poplar in the parts and beech in the plates followed with 19.7 N/mm^2.

Table 2 Coefficient of elasticity calculated in edgewise bending test (mean values)
Tablica 2. Koeficijent elastičnosti izračunan na temelju rezultata testa savijanja (srednje vrijednosti)

Joint type *Tip spoja*	**Wood species** *Vrsta drva*	**Coefficient of elasticity** *Koeficijent elastičnosti* N/mm^2	**Stand. deviations** *Standardna devijacija*
Double dowel *dvostruki moždanici*	Beech / *bukovina*	22.7	2.7
	Poplar / *topolovina*	12.4	2.5
Mortise and tenon *čep s rupom*	Beech / *bukovina*	24.2	3.5
	Poplar / *topolovina*	13.1	3.1
Corner block *kutnici*	Beech / *bukovina*	28.2	5.8
	Poplar / *topolovina*	23.3	3.2
	Beech in the parts and Poplar in blocks *bukovina s topolovim kutnicima*	33.2	5.7
Double gusset plates *dvostruke drvene pločice*	Beech / *bukovina*	37.5	5.7
	Poplar / *topolovina*	21.2	4.0
	Poplar in the parts and Beech in plates *topolovina s bukovim pločicama*	19.7	4.1

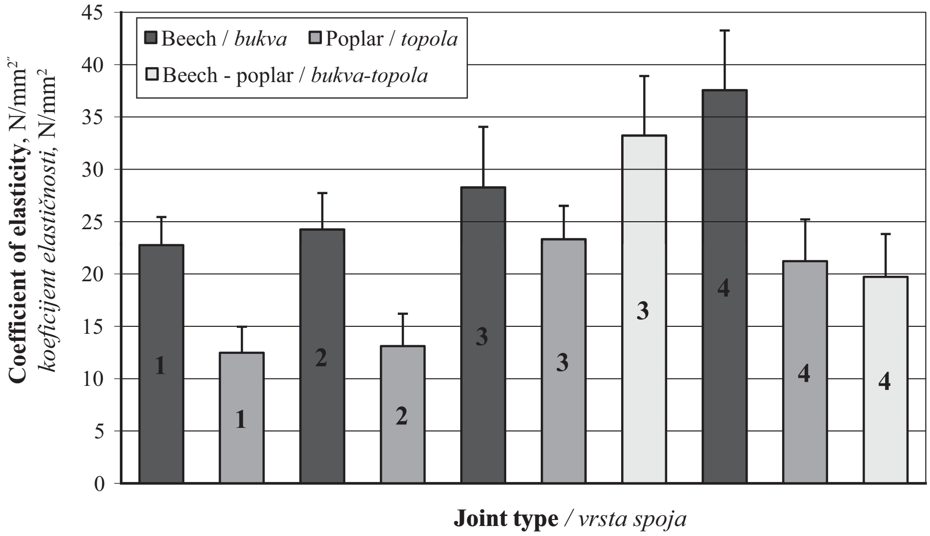

Figure 4 Coefficient of elasticity in edgewise bending strength of middle joints: 1. double dowel joint, 2. mortise and tenon joint, 3. corner blocks, 4. double gusset plates
Slika 4. Koeficijent elastičnosti savijanja drvenih spojeva: A. dvostruki spoj moždanicima, B. spoj čepom i rupom, C. spoj drvenim kutnicima, D. spoj drvenim pločicama

Finally, the mortise and tenon joint made of poplar had a much lower CE value (13.1 N/mm^2) and the double dowel joint made of poplar wood marked the lowest *CE* value of all the joints in this research (12.4 N/mm^2). As can easily be noticed, all the joints in this research, made solely of poplar wood, demonstrated lower coefficient of elasticity values than the corresponding joints made of beech wood. It should also be noticed that the combination of two wood species in the case of double corner blocks proved to be quite effective both in edgewise bending moment capacity and the coefficient of elasticity, while the combination of two wood species in the case of gusset plates failed to give the expected bending force or *CE* value.

According to the results of the variance analysis, statistically significant differences were observed between the following joints: the *CE* value of the double dowel joint made of beech and also the mortise and tenon joint made of beech wood differed significantly from the dowel joint made of poplar, the mortise and tenon joint made of poplar wood, as well as the corner blocks made of a combination of the two species and the gusset plates made of beech wood. Furthermore, the double dowel joint made of poplar wood showed statistically significant differences from all the other joints of this study, except the mortise and tenon joint made of poplar wood. Finally, the coefficient of elasticity of all the versions of the corner block joint showed statistically significant differences from the corresponding value of all the versions of gusset plates, regardless of the material they were made of.

4 CONCLUSIONS
4. ZAKLJUČCI

This research evaluates the strength of the four most frequently used middle joints in the upholstered furniture frames: mortise and tenon, double dowel, corner blocks and double gusset plates. The joints were made of beech and poplar solid wood, in the form of middle joints and the edgewise bending strength of these joints was thoroughly investigated, as well as the coefficient of elasticity. Based on the results, the following conclusions can be drawn:

- The double dowel joint made of beech wood was proved to be the most durable joint of these four joints regarding the edgewise bending force, while the corner block joint made of beech and also made of a combination of two wood species (beech in the parts and poplar in corner block) resulted in a little lower strength values. Additionally, apart from the high value of the bending force, the corner block joint was proved to be characterized by quite a satisfying value of coefficient of elasticity.
- The double gusset plate joint made of poplar showed medium edgewise bending force, whereas the same joint made of beech resulted in even lower strength. Consequently, the gusset plates should be made of poplar, especially when the load that dominates in the structure is edgewise bending. Nevertheless, the specific joint indicated the highest coefficient of elasticity of all four joint types.
- The mortise and tenon joint was proved to be less durable in edgewise bending forces, especially when made of poplar. So, this particular joint did not provide the expected strength and also demonstrated among the lowest coefficients of elasticity.
- The lowest coefficient of elasticity in edgewise bending test was measured in the double dowel joint made of poplar wood.
- The combination of two wood species in the case of double corner block joint was proved to be quite effective both in edgewise bending force and in elasticity, while the combination of two wood species in the case of gusset plates failed to give either the expected bending force, or the elasticity value.

- Finally, the joints made of beech proved to be characterized by higher values of edgewise bending force and coefficients of elasticity compared to the corresponding values of joints made of poplar.

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Thermal Comfort While Sitting on Office Chairs – Subjective Evaluations

Toplinska ugodnost sjedenja na uredskim stolcima – subjektivne procjene

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ABSTRACT • *Thermal comfort is related to human physiological reactions. In order to maintain a constant internal temperature, the human body must dissipate heat in a warm climate, and prevent heat losses in a cold climate. The overall sensation of comfort accompanies the warmest part of the body in a warm environment and the coldest one in a cold environment. Chair design and clothing may affect the difference in sensitivity between certain parts of the body, that is, they may affect thermal comfort. This research focused on subjective sensation of warmth and moisture while sitting on office chairs. The subjective method of evaluating thermal discomfort is based on ISO 7730:2005 standard, according to which a questionnaire was made for this research. Six subjects took part in the research. They were sitting on five different office chairs as they performed their usual jobs in controlled conditions. From the point of view of the evaluation of the sensation of warmth, all chairs were evaluated neutrally. The sensation under the buttocks and thighs was reported to be somewhat warmer, while the sensation on the back was reported to be somewhat colder, which was affected by the design of the back of the chair. No correlation has been proven between the actual temperature and moisture measurements and subjective evaluations of thermal comfort, in spite of a number of direct links. The use of the present method offers the possibility of further research into this subject, which would prove more thoroughly a correlation between design and construction solutions of office chairs and the comfort perceived by sitting persons.*

Keywords: *office chair, seating, sitting, thermal comfort, PU-foam, design, construction, subjective method.*

SAŽETAK • *Toplinska ugodnost povezana je s fiziološkim reakcijama osoba. Kako bi zadržalo stalnu unutarnju temperaturu, tijelo mora oslobađati toplinu u toploj klimi, a sprečavati gubitke topline u hladnoj klimi. Ukupan osjećaj udobnosti prati najtopliji dio tijela u toplom okružju i najhladniji u hladnom okružju. Dizajn stolca i odjeća mogu utjecati na razliku u osjetljivosti između nekih dijelova tijela, odnosno mogu utjecati na toplinsku ugodnost. U radu su istraživani subjektivni osjećaji topline i vlage pri sjedenju na uredskim radnim stolcima. Metoda subjektivne procjene toplinske udobnosti temelji se na normi ISO 7730:2005, prema kojoj je napravljen upitnik za ovo istraživanje. U ispitivanju je sudjelovalo šest ispitanika koji su sjedili na pet različitih uredskih stolaca za vrijeme obavljanja uobičajenih radnih zadataka u kontroliranim uvjetima. Sa stajališta procjene osjećaja topline, svi su stolci ocijenjeni neutralno. Ispod stražnjice i bedara osjećaj topline procijenjen je nešto većim, a osjećaj na leđima hladnijim, na što je utjecao dizajn naslona. Korelacije realnih mjerenja temperature i vlage sa subjektivnim procjenama toplinske udobnosti nisu dokazane, unatoč nekolikim izravnim poveznicama. Rad i prikazana metoda otvaraju mogućnost za daljnja istraživanja te problematike kojima bi se detaljnije dokazala korelacija između oblikovno-konstrukcijskih rješenja radnih stolaca i udobnosti sjedenja na njima.*

Ključne riječi: *uredski radni stolac, sjedenje, toplinska ugodnost, PU spužva, konstrukcije, oblikovanje, subjektivna metoda*

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1 INTRODUCTION
1. UVOD

Thermal comfort is related to human physiological reactions. Humans are homeotherms – meaning that they attempt to maintain their internal (core) temperature within an optimum range (around 37 °C). The human body generates energy and exchanges it (absorbs or gives out) with the surroundings. In order to maintain its constant core temperature, the body must dissipate heat in a warm climate and prevent heat losses in a cold climate (Parsons, 2000). Comfort and sensation of individual body parts vary significantly, so that, in a cold climate, hands and feet are colder than the rest of the body parts. The head, which is insensitive to the cold, but sensitive to the warmth, is warmer than other parts of the body in a warm environment. The overall sensation of comfort accompanies the warmest local sensation (the head) in a warm environment and the coldest (hands and feet) in a cold environment. Chair design and clothing may affect the difference in sensitivity between the upper and lower part of the back. The lumbar region needs protection from cooling by good insulation or local warming. The thoracic region should have a possibility of dissipating body heat, i.e. of airing (Arens *et al*., 2006)

The human body generates thermal energy all the time (Grbac and Dalbelo-Bašć, 1994). The regulation of the normal physiological skin microclimate is necessary for the maintenance of the thermal equilibrium between the heat generated by inner metabolic physical processes and the heat lost from the skin in the surroundings (Nicholson *et al*., 1999; Hänel *et al*., 1997). In the early 1970s, Fanger found that being thermally neutral guarantees comfort, because in optimal condition, no specific sensation of feeling warm or cold is to be expected by the subjects (quoted in: Candas, 2005). However, this conclusion does not concern everyone. The same paper says that not being thermally neutral leads to discomfort. ISO 7730 standard, whose questionnaire served as the basis of this research, is based on Fanger's research, which, among other things, provides links to the number of individuals dissatisfied with regard to their thermal sensation, which are symmetric with regard to thermal neutrality.

The change of insulation around the body, i.e. taking off or changing the clothing with materials having poorer insulating abilities, affects thermal comfort. The design of office chairs may also affect thermal comfort. In the study with seven chairs in an air-conditioned room, researchers found insulating values to be in the range of 0.1 clo[1] for a net chair to 0.3 clo for a chair with the seat and the back of PU foam, which means that they are typical for the majority of modern office chairs (McCullough *et al*. (1994), quoted in: Hedge *et al*., 2005). The comparison of three commercially available chairs (Brand *et al.*, 2000) yielded indefinite results about the core temperature. Thermal conditions may differ if an individual is sitting on a chair with PU foam and high values of thermal insulation (clo) compared to a net chair with low values of thermal insulation. The development of gel production technology enabled the production of materials that give the body a sensation of feeling cold because of the more efficient withdrawal of heat from the body, increasing in this way the sensation of thermal comfort. During research into the influence of the design of ergonomic chairs on thermal comfort (Hedge *et al*., 2005), where influences of PU foam, net and gel in seats on thermal comfort and productivity were researched, its authors came to the conclusion that differences in insulating values of individual types of seat have no significant effects on thermal comfort in controlled climate conditions, and that they neither significantly affect productivity. The study found evidence of a gender difference in ratings of thermal comfort, with women reporting cooler conditions than men, with a 1.5 hours exposure to controlled climate conditions.

Lan *et al.* (2008) research into thermal comfort and gender differences also proved the existence of gender differences. Correlations of reported sensation of warmth, the air temperature and water vapor pressu-

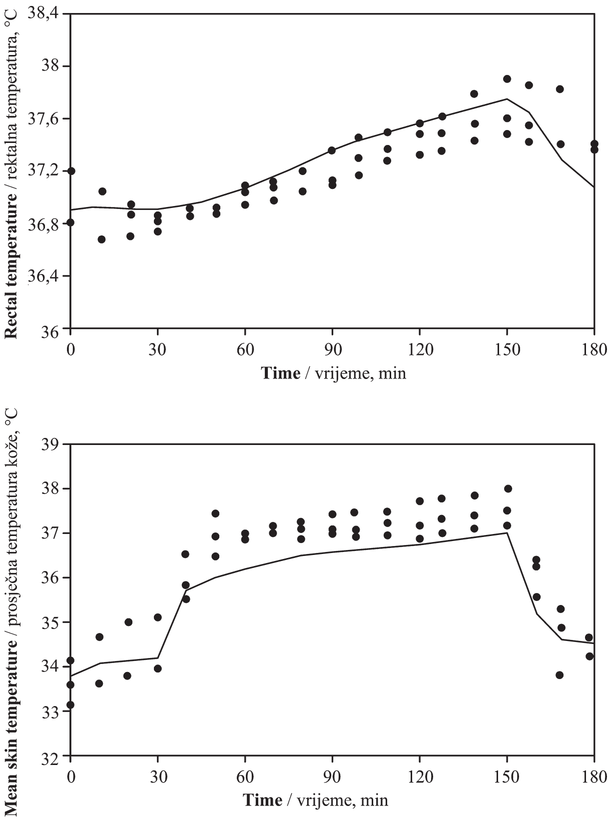

Figure 1 Comparison of the simulation (line) and the experimental results (dots) of a person in cotton clothes (cotton 100 %, 0.195 kg/m^2), sitting during transition from 28 °C to 45 °C and back to 28 °C, RH 40 % (source: Xu and Werner, 1997)
Slika 1. Usporedba simulacijskih (linija) i eksperimentalnih podataka (točke) osobe u pamučnoj odjeći (100 % pamuk, 0,195 kg/m^2) pri sjedenju tijekom promjene temperature sa 28 °C do 45 °C i natrag, uz 40 %-tni RH (izvor: Xu i Werner, 1997)

[1] Clo is a unit for measuring thermal isolation of clothes, and it amounts to 0,18 m^2·°C·h/kcal = 0.155 m^2·°C/W.

re showed that women are more sensitive to warmth and less to humidity than men. Analyses of subjective evaluations, the skin temperature and heartbeat variability, made within the same research, showed that females prefer neutral or slightly warmer conditions with regard to their permanently lower skin temperature and the fact, that the mean skin temperature is a good predictor for sensation and discomfort below the neutral. The comfortable operative temperature for women (26.3 °C) is higher than the one for men (25.3 °C), although both genders have almost the same neutral temperatures. Therefore, in the neutral area, i.e. in neutral conditions, there are no significant differences in the sensation of warmth with regard to gender. Research into changes of thermal insulation of a person while sitting showed that in case of office chairs, an insulation increase by 0.04-0.17 clo depends on the height of the back of the chair and the seat thickness, while in case of a metal chair with a net or a wooden chair, a reduction in insulation of 0.03 clo was recorded. This can be explained by the fact that these chairs behave as "cooling flanges", rejecting the heat due to their high conductivity (Nilsson and Holmer, 1994). For a sitting individual, the chair may significantly affect the heat exchange and hence affect thermal comfort. In spite of these facts, literature on the influence of different seats on thermal insulation is scarce. A comparison between the thermal comfort of seat materials of different wheelchairs and office chairs showed that there are variations between chairs with regard to body parts touching the chair, i.e. the rear part of the thighs, the buttocks and the lower part of the back. With regard to the skin temperature of the subjects, there were no statistically significant differences between the chairs. A wheelchair with the PVC coating material was colder on the rear part of the thighs by some 0.4-0.8 °C when compared to other wheelchairs, colder by 1.7 °C than the office chairs (wool, viscose), and in the lumbar region by 1.1-1.3 °C than the rest. The same research showed that chair temperatures differed by 3.9 °C between the warmest and the coldest part of the back and the seat. The wheelchair coated with PVC proved to be by far the most cold, while the office chairs proved to be by far the warmest statistically (Humphreys *et al.* 1998). The two most significant factors of the overall sensation of warmth were the person's activity and insulating abilities of clothing.

Zacharkow (1988) found that the resistance to the exchanges of heat and moisture acceptance and withdrawal on the area of contact between the body and the pad is strongly connected with the size of the contact area and the contact pressure. The sensation of comfort is, therefore, connected with the parameters of pressure, temperature and relative moisture on the point where the body and the pad touch. Therefore, upholstery materials must enable the transfer of moisture when touching the body. Hänel *et al.* (1997) showed that below a certain degree of compression, moisture and heat are mostly transported in the surface layer, while Shitzer *et al.* (1978) revealed that subjects determine the comfortable temperature for themselves according to variations of their own body temperature. "The ideal" environmental temperature varies from one person to another and in the course of time with regard to variations of the body temperature. Therefore, thermal comfort is related to the body temperature.

Moisture is, beside temperature, another important factor of comfort. Besides warmth, the human body constantly excretes moisture (liquid) through the skin. According to Reed *et al.* (1994), a sitting person perceives moisture on the skin surface as discomfort (quoted in: Stumpf *et al*., 2002), because wet skin increases the friction coefficient, causes sticking to clothing or chair upholstery and prevents small movements necessary to shift the weight from the pressure points (Hänel *et al*., 1997). Therefore, a moisture increase on the skin surface leads to uncomfortable sitting. The sleeping quality, for example, depends on materials touching the body, liquid absorption capacity and temperature (Grbac and Dalbelo-Bašić, 1994). Excessive skin hydration due to accumulated moisture changes its characteristics. Wet tissue is mechanically weaker than dry tissue (Park and Baddiel, 1972), which leads to increased wetting and wounds (decubitus ulcer). Moisture increases the resistance coefficient between the individual and the pad. Such increased resistance, when a patient is sliding against the bed sheet for example, may cause, together with a pressure increase, skin blisters and, finally, surface erosion (Sulzberger *et al*., (1966), Dinsdale (1974), quoted in: Nicholson *et al*., 1999). Research (Davies and Mills, 1999) into characteristics of slow regenerating foam with half-closed cells (mark CF-45) demonstrated that mechanical characteristics are very much dependant on temperature and humidity, but these effects were not researched in sitting experiments. Previous testing within research into the distribution of pressure while sitting on slow recovery PU foam (Davies *et al*., 2000) showed that, when a 25 mm thick layer of such foam is exposed to the temperature of 35 °C and relative humidity of 80 %, it takes two hours for humidity contents to achieve equilibrium. It is probable that short sitting tests were mostly affected by air circulation, not so much by humidity input (Davies *et al*., 2000).

When it comes to thermal comfort, the emphasis is, therefore, on how to achieve and maintain thermal equilibrium of the body by changing postures. The posture in thermal comfort may be defined as resistant or compensational adjustment of different bodies to the partial change of the effective size of the body surface for heat exchange (Raja and Nicol, 1997). As far as the seat construction or structure is concerned, and taking into account climate and physiological facts, there are, according to Kurz *et al*. (1989), no significant differences between seats made entirely of foam and layered with springs, rubberized coconut fibers and coating materials. Seat and back upholstery of office chairs made of PU foam are usually covered with materials having insulating abilities and preventing in this way the withdrawal of heat from the body (quoted in Stumpf *et al*. 2002; Bartels, 2003). Nicholson at al. demonstrated to which extent foam limits heat transfer and that

At this moment, how do you feel your...? / *kakav osjećaj topline u vome trenutku imate...?*

		Cold hladan	Cool prohladan	Slightly cool slabo prohladan	Neutral neutralan	Slightly warm malo topao	Warm topao	Hot vruć
1.	**Under thigh** / ispod bedara	1	2	3	4	5	6	7
2.	**Inner thigh** / unutar bedara	1	2	3	4	5	6	7
3.	**Stomach** / u području trbuha	1	2	3	4	5	6	7
4.	**Side of body** / na bočnim stranama tijela	1	2	3	4	5	6	7
5.	**Chest** / u području prsa	1	2	3	4	5	6	7
6.	**Waist** / u području struka	1	2	3	4	5	6	7
7.	**Back** / na leđima	1	2	3	4	5	6	7
8.	**Bottom** / na stražnici	1	2	3	4	5	6	7
9.	**Head** / na glavi	1	2	3	4	5	6	7
10.	**In general** / općenito	1	2	3	4	5	6	7

Figure 2 The first section of the questionnaire about thermal comfort with the answers-scores offered
Slika 2. Izgled prvog dijela upitnika o toplinskoj ugodnosti s ponuđenim brojčanim odgovorima

the cover is the limiting factor of the evaporation rate. Heat transfer is also limited by the resistance to imperceptible (latent) heat loss through the covers (Nicholson *et al*., 1999). PU foam pads also make moisture transfer from the skin surface more difficult. Diebschlag et al. (1988) revealed that besides different foam composition, its permeability depends on pressure, which signals that thermal comfort varies for different people using the same office chair, depending on where and how much they press the foamy seat and back upholstery. Fisher *et al*. (1978) studied different materials used for wheelchair seat cushions and found a significant rise in skin temperatures under the thighs and sitting bones of test subjects sitting on 10 cm thick foam rubber pads (quoted in: Stumpf *et al*., 2002).

The present research had two goals. The first was to explore thermo-physiological sensations on a selected number of subjects while sitting on different types of seats. In addition, the questionnaire was tested as well as its sensitivity in order to establish its reliability for future research of this type. The second goal of this research was to establish correlations between subjective and objective results into thermal comfort while sitting. Besides the basic research, in its last part, the paper presents the correlations with objective measurements of temperature and moisture while sitting on the same type of chair (results published by Vlaović *et al*., 2012).

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The method of subjective evaluation of thermal comfort is based on standard ISO 7730:2005 Moderate thermal environments – Determination of the PMV and PPD indices and specification of the conditions for thermal comfort, which describes how to measure thermal comfort by using a dummy or a person. The questionnaire for this research was modeled after it (Cengiz and Babalik, 2007).

The questionnaire was made up of four sections: sensation of warmth on ten different body regions, body moisture on two body regions, thermal comfort on a chair, and sweating level. Each of the four sections was developed as a scale offering a particular range of levels as possible answers (Vlaović, 2009).

"The warmth sensation scale" was, for instance, a seven-level scale (cold [1], cool [2], slightly cool [3], neutral [4], slightly warm [5], warm [6] and hot [7]) offering answers to the question: *At this moment how do you feel your…?* (Figure 2).

In order to make the understanding of the question easier, the warmth sensation section of the questionnaire was accompanied by a graphic presentation of the specific points on the body to which the question referred (Figure 3).

"The body moisture scale" consisted of four levels (dry [1], slightly wet [2], humid [3], and wet [4]) to answer the question *How do you feel body moisture on your…?* "The scale of thermal comfort on a chair" had three levels (low [1], medium [2], and good [3]) to answer the question *How is comfort on…?* "The sweating level scale" consisted of four answers (absent (1), low (2), medium (3), and much (4) to answer the question *How is your sweat level?* Each answer offered for a particular question from the above four groups was shown numerically and the subjects answered by circling the appropriate answer.

Number in the figure correspond to questions 1 to 8, and represent the spot of heat feeling.
Broj na slici odgovara pitanjima od 1. do 8., a predstavlja mjesto osjećaja topline.

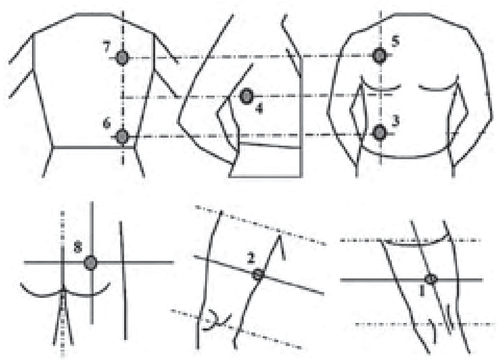

Figure 3 Schematic representation of a sense of warmth (source: Cengiz and Babalik, 2007)
Slika 3. Shematski prikaz mjesta osjećaja topline (izvor: Cengiz i Babalik, 2007)

a) Model M1 b) Model M2 c) Model M3 d) Model M4 e) Model M5

Figure 4 Samples of office chairs
Slika 4. Uzorci uredskih radnih stolaca

Measurements were carried out in the air-conditioned room at the mean temperature of 23.94 °C and relative humidity of 46.43 % throughout six days. According to the pre-determined schedule, six subjects were tested on five selected chairs, using two chairs per day, for 90 minutes each.

2.1 Samples
2.1. Uzorci

The study used five models of office chairs (Figure 4). The samples were selected according to the principles of proper body support in the working posture and the constructions that enable proper and comfortable sitting posture as a pre-condition for comfort (Vlaović *et al*., 2008, Vlaović *et al*., 2010). In addition, attention was paid to compliance of the samples with the current standards regarding functional dimensions. Every sample is detailed in Table 1. Cover material composition of all seats was 100 % polyester, and seat thickness was 60 mm or 55 mm (models M3 and M4). Material make of all seats was non-hygroscopic. Detailed seat characteristics are presented in by Vlaović *et al*. (2012).

2.2 Subjects
2.2. Ispitanici

The study included six healthy subjects. The subjects' details are given in the following table.

In order to minimize the influence of clothing, the subjects were wearing cotton underwear and light linen or cotton clothing. Prior to measurement, height of the seats and armrests had been tuned to every subject in order to ensure maximum comfort according to the table height, as required by the corresponding basic ergonomic criteria.

Table 1 Characteristics of seat construction of models of office chairs
Tablica 1. Konstrukcijska obilježja sjedala modela uredskih stolica

Model	M1	M2	M3	M4	M5
Seat construction *konstrukcija sjedala*	Slabstock foams: *rezana spužva:* 40 mm PT3246*** 20 mm PG65120*	Slabstock foams: *rezana spužva:* 20 mm VISCO*** 20 mm PT3246** 20 mm PG65120*	Molded PU-foam: *hladno lijevana spužva:* 10 mm PU 4040 *** 45 mm pocket springs *džepićaste opruge** (D45 mm / r1.8 mm)	Molded PU-foam: *hladno lijevana spužva:* 55 mm PU 4040	Slabstock foam: *rezana spužva:* 60 mm PT3246
Total density *ukupna gustoća*	41.3 kg/m^3	48.5 kg/m^3	40 kg/m^3	40 kg/m^3	28.3 kg/m^3

*** = upper layer material / *materijal gornjeg sloja*, ** = middle layer material / *materijal srednjeg sloja*,
* = lower layer material / *materijal donjeg sloja*

Table 2 Anthropometric characteristics of subjects
Tablica 2. Antropometrijske osobine ispitanika

Subjects' code *Oznaka ispitanika*	**Age, year** *Starost, godine*	**Height** / *Visina,* cm	**Mass** / *Masa,* kg	**BMI,** kg/m^2
Female 1	37	166	61	22.1
Female 2	43	164	70	26.0
Female 3	33	166	65	23.6
Male 4	29	182	68	20.5
Male 5	34	184	79	23.3
Male 6	34	181	91	27.8
Minimum	29	164	61	20.53
Maximum	43	184	91	27.78
Mean	35	173.8	72.33	23.90
SD	4.28	8.57	9.99	2.40

Mean – arithmetical mean / *aritmetička sredina;* SD – standard deviation / *standardna devijacija;*
BMI – body mass index / *indeks tjelesne mase*

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Subjective evaluations of thermal comfort by the selected sample of subjects while sitting on office chairs and performing their everyday jobs gave the results shown in the following tables.

Most subjects circled the neutral answer, i.e. mark four, when answering to the questions about the sensation of warmth on certain body part and the head. The average mark for answers given by the subjects is therefore 4.46. Looking at the values in Table 3, we notice somewhat higher average mark on points T1, T2 and T8 which represent sequentially the sensation of warmth under the thighs (5.40), the sensation of warmth on the inner thighs (4.74) and the sensation of warmth on the buttocks (5.37).

With regard to the sensation of moisture on the front and rear part of the torso and the sweating level of the whole body while sitting (Table 4), the answers are in the lower scale range of four levels. The marks for moisture on the torso are 1.17 and 1.23 (at the front and on the back). The average mark for the sweating level is 1.73. The lowest mark for the sweating level was given to the model M3 (1.33), and the highest to model M1 (2.00).

With regard to questions about the thermal comfort of the chair relating to the seat and the back (Table 4), the average mark given was 1.87. The thermal comfort of the seat (1.90) and the thermal comfort of the back (1.83) were marked approximately the same, while the highest average marks were given to the seat of the model M3 (2.33) and to the backs of models M1 (2.33) and M5 (2.00).

3.1 Correlations between subjective evaluations of thermal comfort and objective temperature and moisture measurements
3.1. Korelacije subjektivnih procjena toplinske udobnosti s objektivnim mjerenjima temperature i vlage

As described above, the questions from the questionnaire are related to the precisely determined points of sensation of warmth or moisture on the body. The questions about some sensations were directly related to probe locations, which measured the actual temperature and relative humidity occurrences while sitting. This especially concerns the following measuring points: T1 – *At this moment how do you feel your under thigh*?, T2 – *At this moment how do you feel your inner thighs?* and T8 – *At this moment how do you feel your bottom?* (Table 5).

After a thorough analysis and the determination of the non-existence of connections on the level of an individual seat, results were aggregated, which means that the average values of temperature and moisture, measured by 1-A, 3-B and 5-C probes, and measures of subjective evaluations of thermal comfort were determined.

Table 3 Subjective evaluations of chairs on points T1 to T8, of thermal sensation on the head and overall thermal sensation
Tablica 3. Subjektivne procjene stolaca na točkama od T1 do T8, osjećaja topline na glavi i općeg osjećaja topline

Model		At this moment, how do you feel your…? *Kakav osjećaj topline u ovome trenutku imate…?*									
		T1	T2	T3	T4	T5	T6	T7	T8	Head *Na glavi*	In general *Općenito*
M1	Mean	5.50	5.00	4.50	4.33	4.17	4.50	4.33	5.33	4.33	4.67
	SEM	0.22	0.37	0.34	0.21	0.17	0.34	0.61	0.21	0.21	0.33
	SD	0.55	0.89	0.84	0.52	0.41	0.84	1.51	0.52	0.52	0.82
	Min	5	4	4	4	4	4	3	5	4	4
	Max	6	6	6	5	5	6	7	6	5	6
M2	Mean	5.17	4.67	4.00	3.67	3.83	4.00	3.67	5.00	4.00	4.17
	SEM	0.31	0.33	0.00	0.21	0.17	0.26	0.42	0.26	0.26	0.31
	SD	0.75	0.82	0.00	0.52	0.41	0.63	1.03	0.63	0.63	0.75
	Min	4	4	4	3	3	3	2	4	3	3
	Max	6	6	4	4	4	5	5	6	5	5
M3	Mean	5.33	4.67	4.00	4.33	3.67	4.17	5.33	5.67	4.33	4.33
	SEM	0.33	0.33	0.26	0.21	0.21	0.31	0.33	0.42	0.21	0.33
	SD	0.82	0.82	0.63	0.52	0.52	0.75	0.82	1.03	0.52	0.82
	Min	4	4	3	4	3	3	4	4	4	3
	Max	6	6	5	5	4	5	6	7	5	5
M4	Mean	5.67	4.67	4.50	4.00	4.00	4.00	3.33	5.33	4.00	4.33
	SEM	0.33	0.33	0.34	0.52	0.26	0.26	0.56	0.56	0.26	0.42
	SD	0.82	0.82	0.84	1.26	0.63	0.63	1.37	1.37	0.63	1.03
	Min	5	4	4	2	3	3	1	3	3	3
	Max	7	6	6	6	5	5	5	7	5	6
M5	Mean	5.33	4.67	4.17	4.17	3.67	4.17	4.17	5.50	4.33	4.50
	SEM	0.33	0.33	0.17	0.17	0.42	0.31	0.40	0.34	0.42	0.34
	SD	0.82	0.82	0.41	0.41	1.03	0.75	0.98	0.84	1.03	0.84
	Min	4	4	4	4	2)	3	3	4	3	4
	Max	6	6	5	5	5	5	6	6	6	6

T1 – Under thigh / *ispod bedara*; T2 – Inner thighs / *unutar bedara;* T3 – Stomach / *u području trbuha;* T4 – Side of body / *na bočnim stranama tijela;* T5 – Chest / *u području prsa;* T6 – Waist / *u području struka;* T7 – Back / *na leđima;* T8 – Bottom /*na stražnjici*

Table 4 Subjective evaluations of chairs according to the sensation of moisture, thermal comfort and sweating level
Tablica 4. Subjektivne procjene stolaca prema osjećaju vlažnosti, toplinskoj ugodnosti i stupnju znojenja

Model		How do you feel body moisture on your…? *Kakav osjećaj tjelesne vlage imate na…?*		How is comfort on…? *Kakva je ugodnost na…?*		How is your…? *Kakav je vaš…?*
		Torso front *Prednjem torzu*	Torso back *Stražnjem torzu*	Seat back *Naslonu*	Seat cushion *Sjedalu*	Sweat level *Stupanj znojenja*
M1	Mean	1.17	1.33	2.00	2.00	2.00
	SEM	0.17	0.33	0.37	0.00	0.45
	SD	0.41	0.82	0.89	0.00	1.10
	Min	1	1	1	2	1
	Max	2	3	3	2	3
M2	Mean	1.00	1.00	1.83	1.67	1.83
	SEM	0.00	0.00	0.31	0.21	0.31
	SD	0.00	0.00	0.75	0.52	0.75
	Min	1	1	1	1	1
	Max	1	1	3	2	3
M3	Mean	1.17	1.50	2.33	1.67	1.33
	SEM	0.17	0.22	0.33	0.21	0.21
	SD	0.41	0.55	0.82	0.52	0.52
	Min	1	1	1	1	1
	Max	2	2	3	2	2
M4	Mean	1.33	1.17	1.83	1.83	1.83
	SEM	0.21	0.17	0.31	0.17	0.17
	SD	0.52	0.41	0.75	0.41	0.41
	Min	1	1	1	1	1
	Max	2	2	3	2	2
M5	Mean	1.17	1.17	1.50	2.00	1.67
	SEM	0.17	0.17	0.22	0.00	0.21
	SD	0.41	0.41	0.55	0.00	0.52
	Min	1	1	1	2	1
	Max	2	2	2	2	2

Mean – arithmetical mean / *aritmetička sredina;* SEM – standard error of arithmetic mean / *standardna pogreška aritmetičke sredine;* SD – standard deviation / *standardna devijacija*

Table 5 Correlation between thermal comfort and the values of temperature and moisture measurements
Tablica 5. Povezanost toplinske ugodnosti s izmjerenim vrijednostima temperature i vlage

Probe *Sonda*		**Measurement points** / *Mjerne točke*		
		T1	T2	T8
3-B t, °C	*r*	.762	-.175	.626
	p	.078**	.740	.183
3-B %, RH	*r*	-.249	-.110	-.319
	p	.634	.835	.538
5-C t, °C	*r*	.580	-.199	.447
	p	.227	.706	.374
5-C %, RH	*r*	.455	-.439	.306
	p	.365	.384	.555
1-A t, °C	*r*	.649	-.379	.478
	p	.163	.458	.337
1-A %, RH	*r*	-.002	-.222	-.099
	p	.997	.672	.853

** significant difference of 10 % / *razlika značajna na razini od 10 %*

Note: Probe 1-A (t °C) and (% RH): temperature and moisture under the gluteus on the seat; Probe 3-B (*t*, °C) and (% RH): temperature and moisture under the thigh on the seat; Probe 5-C (*t*, °C) and (% RH): temperature and moisture in the centre of the seat between the lower extremities; r – Pearson's coefficient of correlation; *p* – difference significance (because of the small number of subjects in experiment, a milder significance criterion was applied i.e. $p<0.10$); T1 – Under thigh; T2 – Inner thighs; T8 – Bottom / *Napomena: Sonda 1-A (t, °C) i (% RH): temperatura i vlaga ispod gluteusa na sjedalu; sonda 3-B (t, °C) i (% RH): temperatura i vlaga ispod natkoljenice na sjedalu; sonda 5-C (t °C) i (% RH): temperatura i vlaga na sredini sjedala, između nogu ispitanika; r – Pearsonov koeficijent korelacije; p – razina značajnosti (zbog malog broja ispitanika primijenjen je niži kriterij značajnosti od 10 %);* T1 – *ispod bedara;* T2 – *unutar bedara;* T8 – *na stražnjici.*

A correlation was calculated between the said measures, which showed that the temperature measured in the region under the thighs on the seat (3-B) is related to the subjective temperature evaluation in the region under the thighs (T1). The correlation is high and positive, meaning that the higher measured temperature values were perceived as higher by subjects as well ($r = 0.762$; $p = 0.078$). In other cases, the correlation level obtained is not statistically significant ($p > 0.10$).

It is interesting that other correlations did not show any significance. This especially applies to the lack of correlation between T8 and 1-A, although the average rating on T8 is relatively high, as well as the aggregated temperature value of the probe 1-A (it was higher than the temperature of the probe 5-C, but lower than the temperature of the probe 3-B).

This discrepancy could be due to several reasons: because of the constitution and gender differences that have different perceptions of thermal comfort; due to the relatively short sitting; because of the relatively small number of respondents, and thus the small number of data whose differences did not prove significant.

4 CONCLUSION
4. ZAKLJUČAK

Based on the research undertaken on six subjects and based on its results, the following may be concluded:

- From the point of view of the evaluation of the sensation of warmth, all chairs have been neutrally evaluated. The sensation under the buttocks and thighs have been reported to be somewhat warmer, while those on the back have been reported to be somewhat colder. This is understandable with regard to the net construction of the back of the chair.
- It can be concluded that the questionnaire is sufficiently sensitive and reliable for such studies, but testing time should be longer than 1.5 h.
- In this research no correlation has been proven between the actual temperature and relative humidity measurements and subjective evaluations of thermal comfort, although there have several directly linked points.
- All correlations obtained are of low or only of medium intensity and are not significant. Since the experiment included only 6 subjects, a milder significance criterion was applied i.e. $p < 0.10$. Therefore, no valid conclusions can be reached based on these relations.
- Henceforward, accuracy and reliability of the measurement technique should be increased. It could be said that the use of this system in the seats with thin upholstery is limited. Namely, probe size is relatively large with respect to the thickness of the seat, and therefore horizontal embedding is needed to avoid "moving" from the defined measuring point (see paper: Vlaović *et al*. (2012), Fig. 3b).
- Future research should include a greater number of subjects as well as different types of design and construction solutions for office chairs, since the selected method and the questionnaire proved appropriate for research and for obtaining relevant results.

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Bioremediation of Lindane by Wood-Decaying Fungi

Biorazgradnja lindana pomoću gljiva uzročnika truljenja drva

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ABSTRACT • *The object of this paper is to study the ability of four white-rot fungi (Trametes versicolor, Hypoxylon fragiforme, Chondrostereum purpureum, and Pleurotus ostreatus) and one brown-rot fungus (Gloeophyllum trabeum) to degrade the organochlorine insecticide lindane in liquid cultures. The evaluation of lindane biodegradation was performed using two analytical procedures. In order to extract and properly quantify the remaining lindane from fungal liquid cultures, two different extraction procedures were used: extraction from filtrates and extraction from homogenized fungal cultures. White-rot fungi were able to degrade lindane. The amount of degraded lindane increased with its exposure period in the liquid cultures of all white-rot fungi used, except C. purpureum. After 21 days of exposure, over 90 % of lindane was degraded by T. versicolor, H. fragiforme, and P. ostreatus. Degradation of lindane by the brown rot G. trabeum did not occur. The extraction procedures, when liquid cultures of T. versicolor, H. fragiforme, and P. ostreatus were used, had no noticeable effect on the determined degradation after 21 days of exposure. On the other hand, the amount of remaining lindane in liquid cultures of C. purpureum and G. trabeum depended strongly on the extraction procedure. Our study indicates that mycoremediation studies of lindane should also consider adsorption onto mycelial biomass as a possible reason for the removal of the insecticide from the liquid medium, especially where shorter exposure periods are studied or fungi with poorer degradation potentials are used.*

Keywords: *biodegradation, lindane, white rot, adsorption, gas-chromatography*

SAŽETAK • *U radu se prikazuje istraživanje sposobnosti četiriju gljiva bijele truleži (Trametes versicolor, Hypoxylon fragiforme, Chondrostereum purpureum i Pleurotus ostreatus) te jedne gljive smeđe truleži (Gloeophyllum trabeum) za razgradnju organoklorova insekticida lindana u tekućim kulturama. Procjena biorazgradnje lindana izvedena je uz pomoću dvaju analitičkih postupaka. Kako bi se izdvojio i pravilno kvantificirao preostali lindan u tekućim kulturama gljiva, primijenjena su dva različita ekstrakcijska postupka: ekstrakcija iz filtrata i ekstrakcija iz homogenizirane kulture gljiva. Dokazano je da su gljive bijele truleži razgradile lindan. Količina razgrađenog lindana povećava se s trajanjem izlaganja u tekućim kulturama svih gljiva bijele truleži, osim gljive C. purpureum. Nakon 21 dan izloženosti gljivama T. versicolor, H. fragiforme i P. ostreatus više od 90 % lindana bilo je razgrađeno. Razgradnje lindana od gljive smeđe truleži G. trabeum nije bilo. Postupak ekstrakcije imao je zamjetan učinak na razgradnju nakon 21 dan izlaganja tekućoj kulturi gljiva T. versicolor, H. fragiforme i P. ostreatus. Nasuprot tome, količina preostalog lindana u tekućim kulturama gljiva C. purpureum i G. trabeum znatno ovisi o postupku ekstrakcije. Ovaj rad pokazuje da bi se u istraživanju mikorazgradnje lindana trebala razmotriti i adsorpcija na micelije biomase kao mogući razlog za uklanjanje insekticida iz tekućeg medija, posebno kada se proučavaju kraća razdoblja izloženosti ili kada se koriste gljive s manjim potencijalom razgradnje.*

Ključne riječi: *biorazgradnja, lindan, bijela trulež, adsorpcija, plinska kromatografija*

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1 INTRODUCTION
1. UVOD

Lindane (gamma isomer of 1,2,3,4,5,6-hexachlorocyclohexane, γ-HCH) is a persistent chlorinated insecticide, which has been used worldwide mostly in agriculture for pest control as well as for human medicinal applications and wood protection. Besides its high persistence in the environment, lindane also bioaccumulates in fat tissue due to its high solubility in lipids, affecting non-target organisms, also including human beings (Lal and Saxena, 1982; Willet *et al*., 1998; Zucchini, 2009). Use of lindane is therefore prohibited in many countries and it was listed under the Stockholm Convention on Persistent Organic Pollutants in 2009 (UNEP, 2009).

Bioremediation using fungi (mycoremediation) is possible on a wide range of pollutants. In particular, white-rot fungi show the capability of degrading a variety of organopollutants. Degradation of such xenobiotics is thought to involve lignin-degrading system and its extracellular enzymes (laccases, lignin peroxidases and manganese peroxidases). The production of these enzymes is triggered by nutrient deficiency rather than by the presence of the pollutant (Bumpus *et al*., 1985; Kirk and Farrell, 1987). However, there have been reports on the production of ligninolytic enzymes even in nutrient sufficient media (Moreira *et al*., 1997; Janse *et al*., 1998).

Expression of ligninolytic genes in general is repressed by the presence of easily available nutrients (e.g. glucose) and induced in the presence of substrate polymers or their derivatives. Laccase genes are transcribed at low constitutive levels in many basidiomycetous fungi (Cullen, 1997; Aro *et al*., 2005). The expression can be enhanced using inducers such as aromatic compounds, including degradation products of lignin, which also induce expression of other ligninolytic genes (Muñoz *et al*., 1997; Scheel *et al*., 2000).

Several studies have been done concerning fungal degradation of lindane. Reported degradations of lindane with different white-rot fungi vary greatly, with maximum values ranging between over 90 % and less than 5 % (Bumpus *et al*., 1985; Mougin *et al*., 1996; Singh and Kuhad, 1999; Quintero *et al*., 2008). The majority of the studies were performed using *Phanerochaete chrysosporium*, which was reported to be able to degrade a vast variety of organopollutants, including lindane (Bumpus *et al*., 1985; Mougin *et al*., 1996; Pointing, 2001). Mougin *et al*. (1996) and Singh and Kuhad (1999) also reported the identification of polar metabolites produced during fungal degradation of lindane.

In the present research, four white-rot fungi and one brown-rot fungus were exposed to lindane and its degradation dynamics was studied. Since the degradation results in previously published studies were rather diverse and possible adsorption onto mycelial biomass was not always taken into consideration in many of them, two different extraction procedures were used to quantify the remaining lindane in the liquid media in order to determine the actual degradation rates.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Chemicals and fungal cultures
2.1. Kemikalije i kulture gljiva

All chemicals used in the experiment were p.a. grade. Stock solution of lindane was prepared in acetone. Final concentration of lindane in liquid fungal cultures was 30 μM.

Trametes versicolor (L.) Lloyd (ZIM L recently isolated strain), *Pleurotus ostreatus* (Jacq.) P. Kumm. (ZIM L recently isolated strain), *Hypoxylon fragiforme* (Pers.) J. Kickx (ZIM L108), *Chondrostereum purpureum* (Pers.) Pouzar (ZIM L007), and *Gloeophyllum trabeum* (Pers.) Murrill (ZIM L017) were obtained from the ZIM collection (Raspor *et al*., 1995) at the Biotechnical Faculty, Ljubljana and grown on potato dextrose agar (DIFCO Laboratories). For the study of lindane mycoremediation, liquid culture medium as described by Hadar and Cohen-Arazi (1986) was used.

Fungal cultures were grown in 50 mL of liquid medium, inoculated with three mycelial plugs (9 mm in diameter), which were excised from seven-day-old agar cultures of respective fungi. The fungal liquid cultures were kept agitated (100 rpm) on a shaker at 25 °C in the dark for 26 days.

2.2 Exposure of fungal liquid cultures to lindane
2.2. Izlaganje tekućih kultura gljiva lindanu

Four days prior to lindane addition, veratryl alcohol, a fungal secondary metabolite, was added to fungal liquid cultures (final concentration 2 mM) in order to induce the production of ligninolytic enzymes (Faison and Kirk, 1985; Faison et al., 1986; Scheel et al., 2000). Fungal cultures were grown for 26 days and lindane was added 10 minutes, two hours, six hours, one day, three days, and 21 days prior to the end of the experiment. Uninoculated liquid media with addition of lindane (for 10 min and 21 days) and fungal liquid cultures without lindane were kept as controls. All experiments were carried out in triplicates.

2.3 Remaining lindane extraction and GC analysis of the extracts
2.3. Ekstrakcija preostalog lindana i GC analiza ekstrakta

Two different extraction procedures were performed for each set of samples, one from filtrates and the other from homogenates. In the first procedure, hexane (1:1, v/v) was added to the fungal liquid culture and the content of the flask was shaken vigorously for three minutes. To remove mycelial biomass, the mixture was filtrated (Sartorius, Grade 388, 84 g m^{-2}) using a water pump. When necessary, the filtrates were centrifuged (3 min, 4,000 rpm) to separate the aqueous phase from the organic phase, which was then further analyzed for remaining lindane.

In the other extraction procedure, the fungal liquid culture was removed from the Erlenmeyer flask and the flask was washed thoroughly with hexane (50 mL), which was then added to the fungal culture. The obtained mixture was homogenized (T25 Digital Ultra-Turrax, 11,000 rpm, 30 s) and then centrifuged (5 min, 4,000 rpm). The upper, organic phase was removed and subjected to analysis.

Remaining lindane was quantified using gas chromatography (GC). GC analyses were performed by a Hewlett Packard 6890 Series chromatograph (Hewlett Packard) equipped with ECD detector and Restek RTX-5MS capillary column (60 m × 0.25 mm × 0.5 µm). The injector and detector temperatures were 250 °C and 320 °C, respectively. The initial column temperature was 70 °C for 1 min, then increased linearly at 30 °C min^{-1} to 300 °C and finally kept constant for 5 min. The nitrogen carrier gas flow rate was set to 2 mL min^{-1} and 1 µL of sample solution (extracts diluted in hexane, 1:10) was injected each time. The retention time of lindane was 10.9 min.

3 RESULTS
3. REZULTATI

Fig. 1 presents an example of chromatograms. Lindane peak area was much larger when the control sample was analyzed, compared to the sample with *P. ostreatus* exposed to lindane, indicating efficient lindane degradation when fungus was used. In both cases the remaining lindane was extracted after 21 days in the medium.

Fungal degradation of lindane determined with different extraction procedures is presented in Fig. 2.

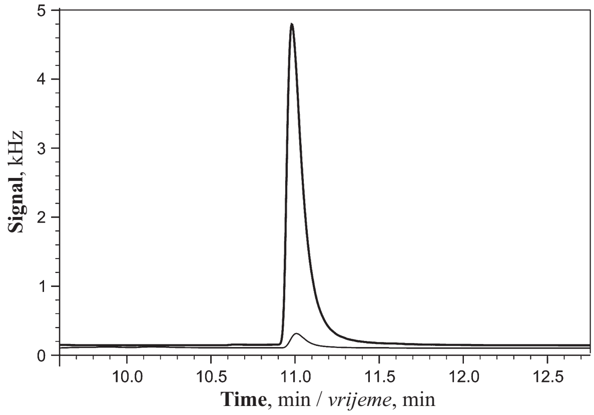

Figure 1 Chromatogram of control sample, represented with the thick line (liquid medium with lindane but without fungal culture), and exposed sample (remaining lindane extracted from homogenised liquid culture of *P. ostreatus*), represented with the thin line, both incubated for 21 days. The ECD detector used in the analyses mainly detects chlorinated compounds and therefore also lindane and its potential degradation metabolites.
Slika 1. Kromatogram kontrolnog uzorka prikazan zadebljanom linijom (tekući medij s lindanom, ali bez kulture gljiva) i izloženi uzorak (preostali lindan ekstrahiran iz homogenizirane tekuće kulture gljive *P. ostreatus*), prikazan tankom linijom, nakon razdoblja od 21 dan. Uz pomoć ECD detektora u analizama uglavnom su otkriveni klorirani spojevi, dakle i linden, te potencijal za razgradnju njegovih metabolita.

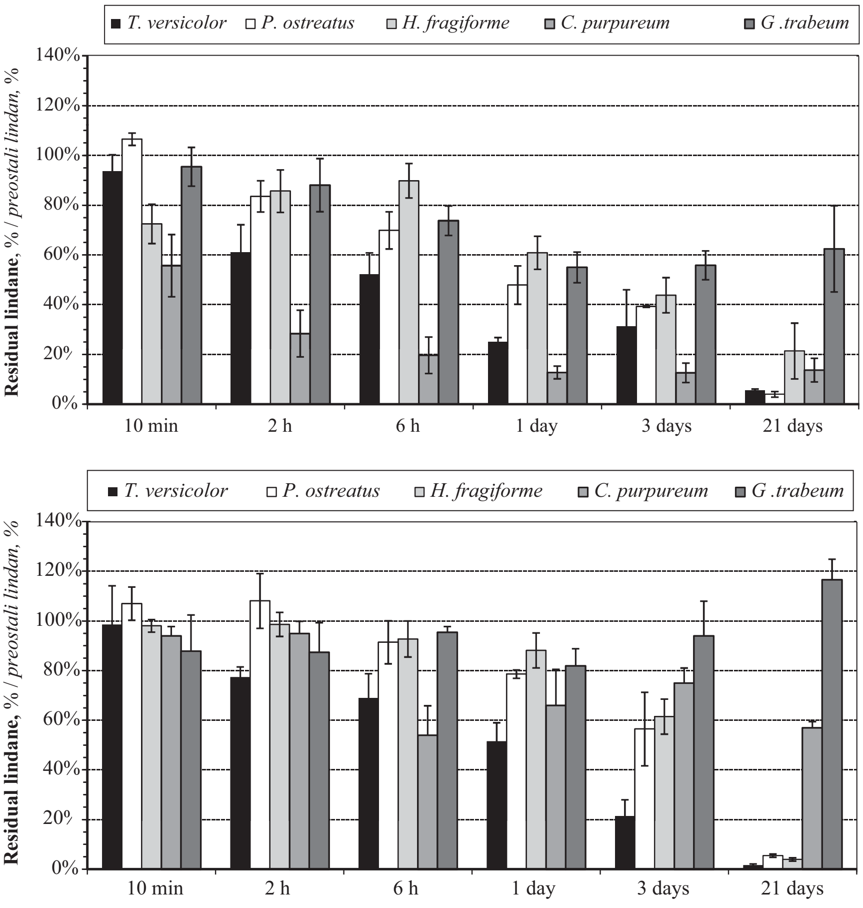

Figure 2 Fungal degradation of lindane. Remaining lindane was extracted from the filtrates of fungal liquid cultures (above) and from homogenized fungal liquid cultures (below).
Slika 2. Razgradnja lindana gljivama. Preostali lindan izdvojen je iz filtrata tekuće kulture gljiva (gore) i iz homogenizirane tekuće kulture gljiva (dolje).

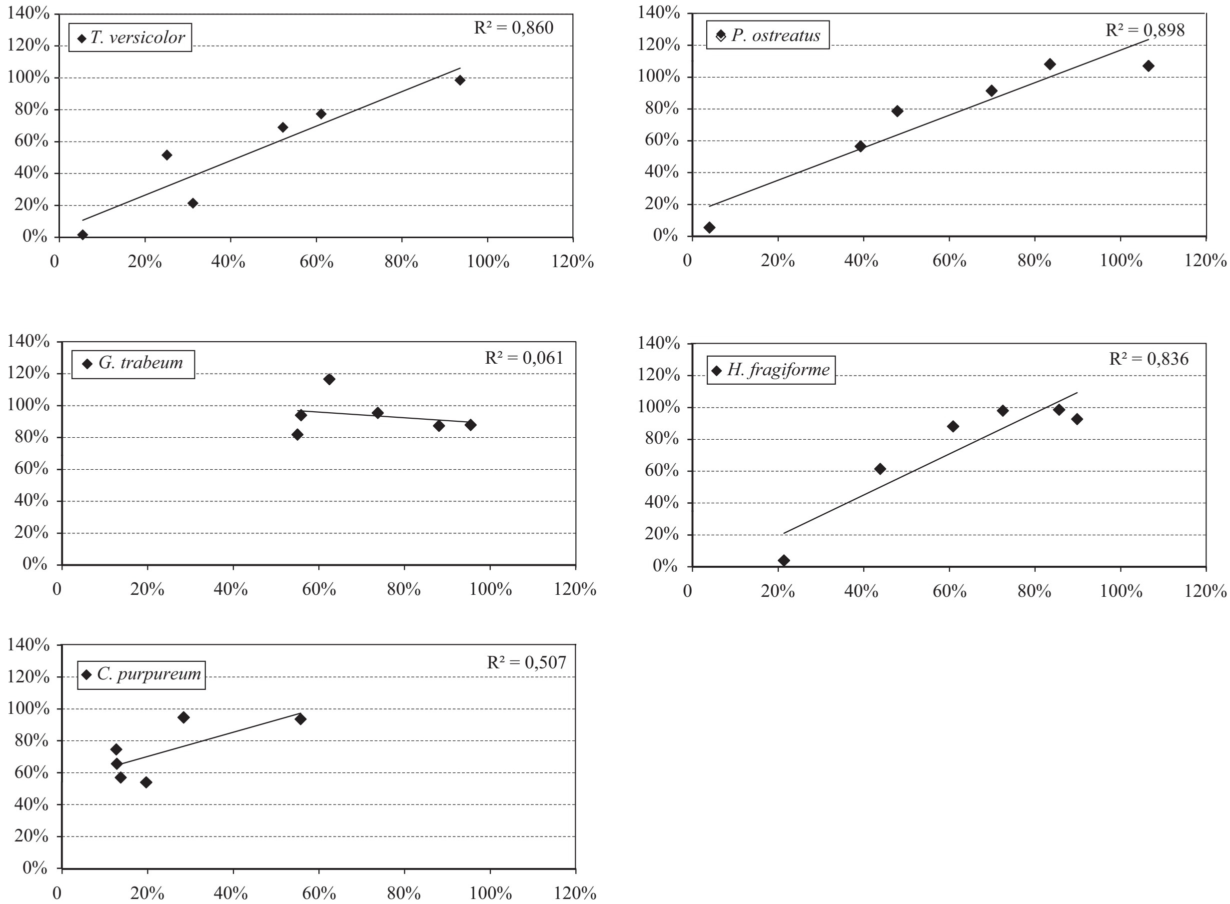

Figure 3 Correlation between extraction methods. The amount of residual lindane obtained with filtration of fungal liquid cultures is plotted on the x-axis and the amount of residual lindane obtained with homogenization of fungal liquid cultures is plotted on the y-axis.
Slika 3. Korelacija među ekstrakcijskim metodama. Količina preostalog lindana dobivena filtracijom tekućih kultura gljiva ucrtana je na *x*-osi, a količina preostalog lindana dobivenog homogenizacijom tekućih kultura gljiva ucrtana je na *y*-osi.

Lindane removal was noticed already after 10 minutes of exposure, regardless of the extraction procedure and the fungal species, except in case of *P. ostreatus*.

After 21 days of exposure in liquid cultures of *T. versicolor*, 98 % of lindane degradation was determined using extraction from homogenized cultures, which was the highest degradation percentage observed (Fig. 2, below). Comparing the two extraction procedures in terms of degradation rates, no significant difference was observed. The course of lindane degradation with *P. ostreatus* resembled that of *H. fragiforme*. Noticeable degradation started between 6 hours and 1 day of exposure, and both fungi degraded lindane significantly after 3 days. After 21 days, less than 10 % of initial lindane was determined. The extraction procedures did not affect the determination of the remaining lindane, as both methods resulted in similar degradation intensities.

Degradation of lindane with *C. purpureum* differed greatly from the degradation with all the other fungi in this experiment. It appeared that all degradation of lindane occurred between 6 hours and 1 day of exposure and the amount of degraded lindane did not change substantially with further increase of exposure time.

Brown rot *G. trabeum* was the least effective in lindane degradation, as expected. The highest removal of lindane was measured after 1 day of exposure, regardless of the extraction method used.

High coefficients of determination (R^2) were observed for *T. versicolor*, *P. ostreatus* and *H. fragiforme* (Fig. 3), indicating a clear correlation between extraction procedures used. Degree of correlation between extraction procedures was significantly lower for *C. purpureum* and practically no correlation was found when *G. trabeum* was studied (Fig. 3).

The experiments showed that in comparison to the controls, the addition of lindane did not inhibit the growth of all examined fungi nor affect it in any other way.

4 DISCUSSION AND CONCLUSIONS
4. RASPRAVA I ZAKLJUČCI

Comparison of the degradation results using *T. versicolor*, *H. fragiforme,* and *P. ostreatus*, obtained with the two extraction procedures, indicates that these fungi degraded lindane and that its removal was not due to adsorption onto the fungal biomass. High R^2 values observed for the linear correlation between residual lindane amounts, which were separately determined in liquid cultures of these fungi with both extraction procedures, further support our findings. In all cases similar degradation intensity was observed. However, it can be seen that differences in the amount of residual lindane, obtained with the two extraction methods are more evident in case of fungi, which lack or exhibit lower remediation potential and in samples where shorter exposure periods were examined. This is in accordance with the hypothesis that lindane is removed from the medium also via adsorption onto mycelia, which is a rather quick phenomenon. After longer exposure periods these differences diminished, as lindane was successfully degraded by fungal enzymes over time. During homogenization of the sample, the whole amount of the remaining lindane in the medium was extracted, including the possible adsorbed portion, making this procedure more suitable for the evaluation of degradation of lindane from the liquid medium.

When exposed to a brown rot *G. trabeum*, low lindane removal was observed, probably all due to adsorption. The same can also be concluded from the respective R^2 value, which does not prove any correlation between extraction procedures. This corresponds to the forecasts, since brown-rot fungi lack the ligninolytic enzymes, which degrade lignin and most likely organopollutants as well. Similar results were obtained with *C. purpureum*, a white-rot fungus, which degraded lindane to a lesser extent than the other white-rot fungi used in this experiment and presumably lindane removal from the culture media occurred by adsorption as well (supported by R^2 value of 0.5). There were major differences in determined degradation intensity of lindane by *C. purpureum* with respect to the extraction procedure used (Fig. 2). In all samples, the amount of extracted remaining lindane was much higher when homogenization was used, indicating that a significant amount of added lindane adsorbed onto the mycelial surface and could not be detected with extraction from filtrates. It can therefore be assumed that *C. purpureum* degraded lindane to a lower extent than the other tested white-rot fungi and that lindane removal from the liquid media occurred not only due to fungal degradation but also as a result of adsorption. Ghosh *et al.* (2009) reported a very fast rate of adsorption of lindane onto the fungal biomass. This coincides with the results of this study, as the amount of lindane, extracted from the filtrates of the cultures of this fungus, exposed to lindane for only 10 minutes, was already significantly lower than in the controls.

Lindane is capable of adsorption onto various surfaces, e.g. glass and fungal mycelia (Young and Banks, 1998; Nollet, 2007; Ghosh *et al.*, 2009). It was therefore suspected that not the full amount of adsorbed lindane could be extracted when extracting lindane from the filtrates. On the contrary, the whole amount of lindane should be extracted from the homogenized liquid cultures. By comparing the measured degradation rates obtained by respective protocols, it is possible to deduce whether lindane was removed from the media because of degradation by the fungi, adsorption onto fungal biomass, or both. Based on our study it can be concluded that adsorption may be one of the mechanisms for lindane removal from the liquid medium. Fungal mycelia, representing extensive potential surface adsorption sites, should therefore also be analyzed for possible adsorption as sole filtered samples taken from the medium are not adequately representative for the degradation analyses.

Interactions between the growth mycelia, fungal enzymes, growth medium, pollutant and its putative metabolites or even growth medium and the pollutant alone contribute to a complex matrix, which makes extraction of organic pollutants difficult, leading to aberrations such as residual lindane exceeding 100 % (Rivero *et al.*, 2012). Homogeneity of fungal liquid cultures, as well as of all other biological systems, is hard to achieve, which together with difficult lindane analytical procedures adds to such deviations.

The chromatograms of the extracts, regardless of the fungal species, contained no additional peaks, which could be correlated to chlorinated degradation metabolites of lindane. Some representative samples were analyzed with gas chromatography coupled to mass spectrometry (data not shown), which also did not confirm any chlorinated products of lindane degradation. Complete absence of any degradation metabolites adds to the obscurity of the degradation mechanism previously described (Mougin *et al.*, 1996; Singh and Kuhad, 1999) and remains the subject of further studies.

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Mogućnosti primjene termografije u hidrotermičkoj obradi drva

Possibilities for Thermography Application in Hydrothermal Wood Processing

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SAŽETAK • *U ovom je radu na temelju dosadašnjih istraživanja dan pregled mogućnosti primjene IC termografije kako u energetskim ispitivanjima hidrotermičkih procesa, tako i u nedestruktivnom ispitivanju drva. Time je ustanovljeno polazište za buduća istraživanja i praktičnu primjenu pri karakterizaciji toplinskih svojstava različitih vrsta drva. Prikazani su eksperimentalni rezultati razmatranja prolaska topline kroz drvo, a primjenom IC termografije omogućeno je otkrivanje grešaka u strukturi materijala poput udubina, truleži i, za proces sušenja najvažnijih, pukotina. Jedan od bitnih ciljeva jest usmjeravanje budućih istraživanja na karakterizaciju toplinskih svojstava domaćih vrsta drva. Drugo moguće područje jest primjena u energetskim ispitivanjima u daljnjemu laboratorijskom i industrijskom praćenju hidrotermičkih procesa.*

Ključne riječi: *IC termografija, svojstva drva, hidrotermička obrada*

ABSTRACT • *This paper gives an overview of possibilities for using IR thermography method. There are two main directions for further research: energy analysis of hydrothermal process and non-destructive evaluation of wood, especially the determination of thermal properties of wood. In this way the starting point has been established for further research and practical application of this method in wood industry. The experimental data of heat flux in wood have been analyzed, and this method can be used for defects detection in material structure, particularly holes, rot and drying cracks. One of the most important future aims is the characterization and research of thermal properties of domestic wood species.*

Key words: *IR thermography, wood thermal properties, hydrothermal processing*

1. UVOD
1 INTRODUCTION

Infracrvena (IC) termografija beskontaktna je metoda mjerenja temperature i njezine raspodjele na površini tijela. Temelji se na mjerenju intenziteta infracrvenog zračenja s promatrane površine. Rezultat termografskog mjerenja jest termogram, koji u sivome ili nekom spektru boja daje sliku temperaturne raspodjele na površini promatranog objekta. Temperaturna raspodjela posredno daje informacije o različitim stanjima same površine promatranog objekta.

Za pravilno razumijevanje termografskog mjerenja i odgovarajućeg termograma bitna su obilježja

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promatranog tijela s obzirom na dolazno zračenje kao i na zračenje koje tijelo emitira u prostor (faktori apsorpcije, refleksije, dijatermije i emisije).

Infracrvena termografija je metoda upotrebe infracrvene termovizijske kamere za prikazivanje i mjerenje toplinske energije koju zrači neki objekt. Zračenje koje dolazi na površinu realnog tijela djelomično se apsorbira, djelomično reflektira, a djelomično ga to tijelo propušta. Omjer između apsorbiranoga i prispjelog zračenja na površinu tijela naziva se faktorom apsorpcije (a), a omjer između reflektiranoga i prispjelog zračenja – faktorom refleksije (r). Većina je inženjerski zanimljivih površina nepropusna (osim nekih materijala kao što su staklo i plastični filmovi) te se cjelokupno dospjelo zračenje na tim površinama djelomično apsorbira, a djelomično reflektira (Andrassy i sur., 2008).

Udio dospjelog zračenja koji će se apsorbirati, odnosno reflektirati ovisi o materijalu i stanju površine te o temperaturi, valnoj duljini dospjelog zračenja i o kutu upada zračenja, a nije zanemariva ni ovisnost o temperaturi zraka. Za inženjersku su primjenu prihvatljivi materijali s prosječnim vrijednostima faktora apsorpcije i faktora refleksije. Zračenje realnih tijela znatno odstupa od zračenja crnog tijela, te je raspodjela intenziteta zračenja prema spektru valnih duljina drugačija.

Netar objekta koji se mora pravilno odrediti jest emisivnost, koja označava mjeru količine zračenja emitiranoga iz objekta u usporedbi sa zračenjem iz savršeno crnog tijela jednake temperature. Faktor emisije (ε) definira se kao omjer vlastite emisije realnog tijela pri određenoj temperaturi i vlastite emisije crnog tijela pri jednakoj temperaturi. Faktor emisije realnih tijela ovisi o temperaturi i stanju površine, te bitno ovisi o kutu otklona od normale na promatranu površinu. Objekt mjerenja, ovisno o materijalu i površinskoj obradi, obično ima faktor emisivnosti od oko 0,1 do 0,95. Faktor emisivnosti polirane površine metala, npr. ogledala, iznosi manje od 0,1, dok, primjerice, oksidirana ili obojena površina ima veći stupanj emisivnosti od polirane površine.

Postoji više čimbenika koji mogu uzrokovati probleme pri mjerenju metodom infracrvene termografije. U osnovne uzroke koji mogu stvoriti takve probleme svrstavaju se udaljenost od kamere do objekta mjerenja, reflektirano zračenje, relativna vlaga, temperatura i brzina strujanja okolnog zraka, količina Sunčeva zračenja, izvedba vanjske optike te prijenos topline.

Uz osnovne, postoje i drugi čimbenici koji mogu rezultirati netočnošću mjerenja poput blizine nekog tijela koje zrači, a ima temperaturu veću od temperature mjerene površine (tzv. reflektirana energija), pa zagrijavanje može ometati rezultate mjerenja. Debljina objektiva na mjernom uređaju može negativno djelovati na mjerenje tako što se određena količina topline koju zrači mjereno tijelo može apsorbirati na objektivu.

S obzirom na to da se stupanj zračenja energije smanjuje s udaljenošću, potrebno je točno odrediti udaljenost između objekta mjerenja i prednje leće objektiva mjernog uređaja. Također treba znati da se uvjeti okoline poput temperature i vlage zraka te udaljenosti od objekta mjerenja uzimaju u obzir radi korekcije jer se dio zračenja apsorbira u atmosferi između objekta i kamere.

Kada je sadržaj vlage u zraku vrlo visok, udaljenost objekta vrlo velika, a njegova temperatura približno jednaka temperaturi okolnog zraka potrebno je napraviti kompenzaciju temperature atmosfere oko objekta.

Kad je riječ o drvu, problem u dosadašnjim termografskim mjerenjima jest prevelika pojednostavnjenost karakterizacije drva kao materijala te se ono, s obzirom na koeficijent emisivnosti, uglavnom svrstava u samo jednu kategoriju i time se smatra homogenim materijalom.

Da to nije prihvatljivo, pokazuje primjer postojanja gradijenta temperature u drvnom elementu pa toplina prelazi iz područja više temperature prema području niže temperature, ovisno o smjeru drvnih vlakanaca. Brzina kojom se ta energija prenosi ovisi o svojstvima materijala te o geometrijskom obliku ispitivanoga drvnog uzorka, što se također vrlo često zanemaruje.

Brzina kojom se neko tijelo hladi (po jedinici površine) naziva se totalnom radijacijom, a definirana je zbrojem reflektirane i emitirane energije.

Rasipanje toplinske energije, tj. hlađenje metalnih materijala vrlo je brzo u usporedbi s drvom, u kojemu gdje taj proces teče izuzetno sporo, te se može zaključiti da drvo dulje zadržava toplinu kojoj je bilo izloženo.

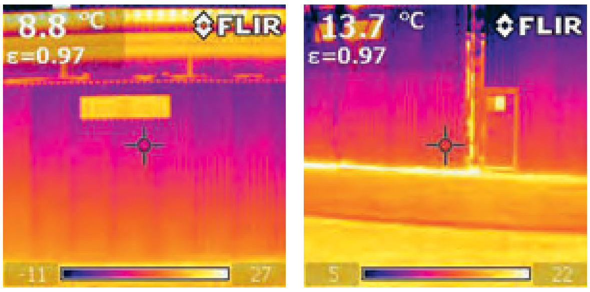
Dva su moguća načina ispitivanja drva metodom termografije – aktivna i pasivna termografija. U aktivnu termografiju pripada proces brzog zagrijavanja drva grijačima, pri čemu temperatura površine brzo raste, dok pasivnoj termografiji pripada proces postupnog zagrijavanja, npr. u proizvodnom procesu, pri kojemu se temperatura nakon napuštanja proizvodnog procesa smanjuje (proces sušenja u sušionicama koji je izuzetno dugotrajan).

U ovom je radu promatrana problematika primjene termografije kao metode analize u drvnoj industriji, u kojoj tehnologija IC snimanja može imati veliko područje primjene. Usto, cilj ovog rada jest prikazati dosadašnja istraživanja te navesti mogućnosti primjene IC termografije u drvnoj tehnologiji, pri ispitivanju različitih svojstava drva kao materijala, s posebnim osvrtom na primjenu u hidrotermičkoj obradi drva.

Metoda termografije pokazala se pogodnom za:

1. kontrolu postrojenja za hidrotermičku obradu drva (sl. 1, 2. i 3), u kojima se utvrđuju zone povišene temperature i, sukladno tome, neželjeni gubici toplinske energije,
2. ispitivanje svojstava drva,
3. otkrivanje grešaka drva.

Postoje i druge mogućnosti primjene IC ispitivanja, poput istraživanja procesa međusobnog „zavarivanja“ drvnih elemenata pri kojima se razvija toplina (Ganne-Chédeville i sur., 2008). IC metodom mjerena je temperatura između drvnih uzoraka te je ustanovljeno točna količina energije potrebne za uspješno zavarivanje (sljubljivanje) drvnih elemenata. IC metodom ispitivanja koristili su se Xu i sur., 1993, za određivanje kvalitete slijepljenosti spojeva.



Slike 1. i 2. Termografska snimka vrata sušionice (strelice označavaju slabo izolirana mjesta)
Figure 1 and 2 Thermographic image of kiln dryer doors (poor insulation marked with arrows)

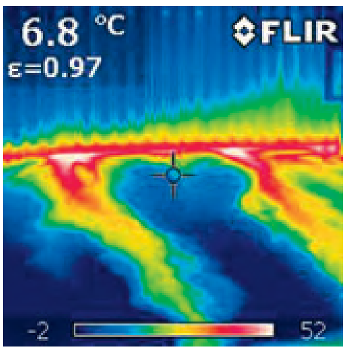
2 IC TERMOGRAFIJA U KONTROLI POSTROJENJA ZA HIDROTERMIČKU OBRADU DRVA
2. IR THERMOGRAPHY IN THE CONTROL OF PLANTS FOR HYDROTHERMAL WOOD PROCESSING

Provedena istraživanja (Pervan, 2009) te analiza rezultata dobivenih tom metodom pokazala su njezinu praktičnu važnost za kontrolu kritičnih mjesta na kojima nastaju toplinski gubici (sl. 1. i 2). Naime, je na temelju snimaka moguće je otkriti svjetlije zone koje označavaju mjesta izlaska zagrijanog zraka zbog lošeg brtvljenja i nedovoljne izolacije postrojenja. Na te spoznaje moguće su pravodobne i ciljane intervencije kojima će se znatno smanjiti toplinski gubici te povećati energetska učinkovitost postrojenja.

Važna mogućnost te metode jest i otkrivanje curenja kondenzata iz parionica (sl. 3), što s vremenom uzrokuje koroziju metalnih dijelova postrojenja (osobito željezne armature), a destruktivno djeluje i na druge materijale od kojih je izgrađeno postrojenje (npr. na betonske temelje).

2.1. Određivanje svojstava drva infracrvenom termografijom
2.1 Determination of wood properties using infrared thermography

U postupku sušenja drvo je, ovisno o primijenjenom režimu sušenja, sklono nastanku pukotina i promjeni oblika. Stoga je metoda IC termografije vrlo pouzdan način potvrde početne kvalitete drva, a služi i kao sredstvo za procjenu smanjenja kvalitete drva tijekom sušenja. Makrodetekcija oštećenja nastalih tijekom sušenja u piljenoj građi dobar je način početnog utvrđivanja nastanka greške na određenome mjestu u drvu ili na njegovoj površini. Za takvu svrhu primijenjena metoda mora biti praktična i pouzdana te istovremeno nedestruktivna, jednostavna za korištenje u praksi i široko primjenjiva, što su uvjeti koje IC termografija u potpunosti ispunjava. Za ispravno razumijevanje termografskog mjerenja te naknadnu analizu termograma, osim obilježja promatranog tijela u odnosu prema zračenju koje na nj dolazi i onoga koje to tijelo emitira u prostor, važno je poznavati toplinska svojstva materijala koji se termografski snima i analizira.



Slika 3. Curenje kondenzata iz parionice ispod vrata
Figure 3 Leakage of condensate from steaming chamber

Glavna toplinska svojstva drva u termografskim provjerama jesu: specifični toplinski kapacitet (c), toplinska vodljivost (λ) i toplinska difuznost (a). Specifični toplinski kapacitet drva određuje se uz pomoć toplinske energije potrebne za promjenu temperature drva s temperature okoline na neku višu temperaturu i mase drva. Specifični toplinski kapacitet drva neovisan je o vrsti drva i gustoći, ali se razlikuje s obzirom na sadržaj vode. Toplinska vodljivost drva količina je toplinske energije koja u jedinici vremena prolazi kroz drvo određene debljine i površine pri stacionarnoj razlici razlika temperature. Ona varira sa smjerom toplinskog toka, ovisno o smjeru vlakanaca, gustoći drva, greškama drva i sadržaju vode u drvu. Toplinska vodljivost drva okomito na vlakanca definirana je (Kollmann i Cote, 1968) za raspone gustoće od 200 do 800 kg/m^3 i pri sadržaju vode od 12 %, što je kasnije primijenjeno za izračunavanje toplinske vodljivosti drva u rasponu od 5 do 35 % sadržaja vode. Ustanovljeno je da suho drvo u smjeru vlakanaca provodi toplinu 2,5 puta brže nego okomito na vlakanca. Taj omjer za vlažno drvo iznosi samo 1,5 jer voda u drvu smanjuje tu razliku. Promatramo li samo smjer okomito na vlakanca, drvo zbog sržnih trakova nešto brže provodi toplinu u radijalnome nego u tangencijalnom smjeru, no slojevi gustoga kasnog drva mogu smanjiti ili naglasiti utjecaj sržnih trakova. Odnos radijalne prema tangencijalnoj vodljivosti iznosi od 0,9 do 1,3, ovisno o veličini i gustoći sržnih trakova te o međusobnom odnosu ranoga i kasnog drva.

Širenje topline u drvu ovisi o difuzivnosti materijala (što je manja volumna masa drva i niži sadržaj vode u njemu, to je veća difuzivnost), stvarnoj promatranoj geometriji te početnim i rubnim uvjetima (Kollmann i Cote, 1968).

Analiza utjecaja površinske temperature i gustoće na termografska mjerenja pokazuje da je složenost rješenja (Kollmann i Cote, 1968) vrlo velika, pogotovo ako se uzmu u obzir stvarni rubni uvjeti pri navedenom istraživanju. Temeljeći ga na proračunima koje je obavio Heisler (1947), Gebhart je (1993) dao grafičko rješenje, za ravni površinski sloj drva. Istaknuo je da površinska temperatura drva ne ovisi samo o trajanju zagrijavanja, početnoj temperaturi drva i zraka nego i o toplinskoj vodljivosti drva. Navodi se da toplinska vodljivost i površinska temperatura drva ovise i o gustoći, pogotovo u području dodira drva sa zrakom. Radi potvrde rezultata navedenih razmatranja u vezi s površinskom temperaturom, Tanaka i Divos (2001) proveli su eksperiment na šest skupina uzoraka (šest različitih vrsta drva), sadržaja vode 12 %, kao predstavnika šest različitih razina gustoće između 265 i 948 kg/m^3, pri čemu su uzorci grijani do temperature od 60 ^{o}C, a naknadno je termokamerom ispitivan proces njihova hlađenja.

Utvrđeno je da je površinska temperatura funkcija gustoće drva te je taj eksperimentalni rezultat bio u skladu s Heislerovim proračunima. Utvrđen je linearan odnos između gustoće i površinske temperature, pri čemu je vrijeme hlađenja iznosilo više od 20 minuta. Na temelju rezultata ustanovljenoje da je termografijom moguće otkriti postojanje kvrge u drvu četinjača jer je gustoća kvrge veća od gustoće okolnog materijala. Osim toga, primjenom termografije moguće je ustanoviti trulež na površini drva s obzirom na to da zaraženo drvo ima manju gustoću od nezaraženoga. Kvrga u drvu listača također se može otkriti, iako nema razlike u gustoći kvrge i drva, ali je različit smjer njihovih vlakanaca, a time i toplinska difuzivnost.

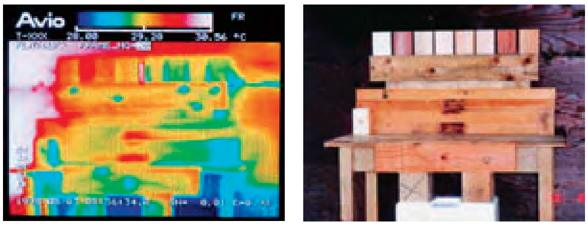
2.2. Otkrivanje grešaka drva
2.2 Detection of wood defects

Primjena IC metode za ispitivanje svojstava drva te za otkrivanje grešaka na drvu ili u njemu vrlo je korisna te je na tim područjima istraživanja ostvaren velik napredak primijenjene IC termografije u drvnoj industriji. Obavljeno je snimanje procesa isušivanja površina drvnih elemenata različite hrapavosti (Aoi i sur., 1998) te je praćen nastanak određenih vrsta pukotina i raspodjela naprezanja u drvu. Pri tim pokusima u analizi je korišten koeficijent varijacije temperature pri kojemu počinje proces sušenja drva. Rezultati su pokazali da suha mjesta koja su se pojavljivala na površini drvnih elemenata uzrokuju pojavu temperaturnih varijacija na cijeloj površini drvnih elemenata. Na temelju toga zaključeno je da površine kao što je drvo, koje pripadaju grubim površinama, bilježe znatan porast koeficijenta varijacije temperature tijekom sušenja.

Mnoge toplinom uzrokovane greške nastale u preradi drva ne mogu se detektirati ni objasniti termalnom analizom zbog prevelike složenosti, nedostatka vremena ili zbog previsoke cijene. Pri ispitivanju postupka ili materijala IC uređajem promatraju se svojstva materijala s kojim se radi, no zbog slabe definiranosti svojstava drva potrebnih za taj tip mjerenja nastaju poteškoće pri rješavanju problema. Većina proizvođača IC mjernih uređaja svrstava drvo u određenu kategoriju s obzirom na koeficijent emisivnosti, pri čemu se ne provodi razvrstavanje prema vrsti drva, gustoći, površinskoj obradi, sadržaju vode i teksturi. Takvim načinom pojednostavnjivanja u potpunosti se zanemaruje varijabilnost i anizotropnost drva te se drvo mjeri kao homogeni materijal.

U prije spomenutim istraživanjima uzorci drva grijani su na relativno visoku temperaturu (60 ^{o}C) te je zatim IC kamerom promatrana prijelazna površinska zona. Tim se načinom drvo izlaže velikim količinama topline, što je vrlo teško primjenjivo na već gotovim građevinskim drvnim konstrukcijama.

Praktičniji način utvrđivanja svojstava drva prikazao je Tanaka (2001) praćenjem dnevnih temperaturnih razlika kao toplinskim pobuđivačem za utvrđivanje svojstava drva.



Slika 4. Termografska (a) i stvarna (b) slika testnih uzoraka postavljenih u vanjskim uvjetima (Tanaka i Divos, 2001)
Figure 4 Thermographic image (a) and real picture (b) of experimental setup (Tanaka and Divos, 2001)

Provedeno je cjelodnevno istraživanje promjena i utjecaja dnevnih temperatura na toplinska svojstva drva da bi se ustanovilo nabolje vrijeme za termografsko snimanje. Upotrijebljeno je šest uzoraka drva različite gustoće, uzorak s truleži i uzorak s kvrgom, koji su smješteni na otvorenome. Svakih deset minuta mjerene su temperature zraka i temperature na površini uzoraka. Uzorci su smješteni u sjenu, pod krov bez bočnih zidova. Takav način izmjere zahtijeva izuzetno veliku preciznost zbog vrlo malih razlika u temperaturi uzorka i okolnog zraka. Autori su naveli da je osnovna prednost te metode jednostavnost i mogućnost vrlo kvalitetnog prikazivanja i analiziranja svojstava drva.

Osim navedene namjene, termografija se uvelike koristi i u nedestruktivnom testiranju različitih materijala, pri čemu je debljina materijala manja od 10 mm. Osjetljivost tehnike ovisi o debljini uzorka koja se određuje u ovisnosti o mogućnosti propaljivanja materijala i toplinskoj vodljivosti drva. Zbog relativno velikih debljina drva, koje je poznato kao dobar izolator (u istraživanju Tanake i Divosa (2001) drvo bilo debljine 45 mm), i zbog slabe toplinske vodljivosti drva otkrivanje rupa bilo je izrazito zahtjevno.

3. ZAKLJUČAK
3 CONCLUSION

IC termografija korisna je potencijalna metoda za energetska ispitivanja hidrotermičkih procesa, kao i za nedestruktivno ispitivanje drva. Pregledom dijela dosadašnjih istraživanja postavljen je temelj za buduća istraživanja i praktičnu primjenu metode pri karakterizaciji različitih vrsta i svojstava drva. Prikazani su i eksperimentalni rezultati prolaska topline kroz drvo pod utjecajima raznih činitelja kao što su gustoća (s utjecajem na površinsku temperaturu) te vodljivost topline koja je različita u različitim anatomskim smjerovima drvnih vlakanaca. Korištenjem IC termografije omogućeno je otkrivanje grešaka u strukturi materijala poput udubina, truleži i za proces sušenja najvažnijih, pukotina. Drugo moguće područje intenzivne primjene navedene mjerne tehnike jesu energetska ispitivanja u daljnjem laboratorijskom i industrijskom praćenju hidrotermičkih procesa. Jedan od važnijih zadataka jest usmjeravanje budućih istraživanja u karakterizaciji svojstava domaćih vrsta drva prema ovim utjecajnim vrijednostima:

- određivanju točnih koeficijenata emisivnosti drva s obzirom na vrstu, sadržaj vode, gustoću i teksturu,
- određivanju vremena hlađenja (površinske temperature drva) u odnosu na gustoću,
- određivanju koeficijenata prolaska topline u odnosu prema sadržaju vode,
- otkrivanju grešaka sušenja (pukotina) tijekom postupka sušenja,
- otkrivanju devijacija strukture drva i postojanja truleži.

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Application of Accounting and Reporting in a Cost-Oriented Quality Management in Wood-Processing Companies

Primjena obračunavanja i izvještavanja u troškovno orijentiranom upravljanju kvalitetom u drvoprerađivačkim tvrtkama

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ABSTRACT • *The company must constantly review its own computer system if it wants to maintain its competitiveness and ensure sustainable development in strong international environment. The company must monitor if the information system provides sufficient information, in terms of quantity and quality, for all its business activities. In order to improve its own position in the market, it must be adequately represented in the quality area, quality costs and the related quality indicators. We offer to companies an option to track quality costs and subsequently evaluate them.*

Keywords: *quality, quality control, quality costs, reporting*

SAŽETAK • *Tvrtka mora stalno ispitivati svoj računalni sustav želi li održavati svoju konkurentnost i osiguravati održivi razvoj u jakome međunarodnom okruženju. Jednako tako, tvrtka mora pratiti pruža li njezin informacijski sustav dovoljnu količinu kvalitetnih informacija u svakom području njezine aktivnosti. Kako bi poboljšala svoju poziciju na tržištu, tvrtka mora biti kvalitetno prezentirana na području kvalitete, troškova kvalitete i pokazatelja kvalitete koji su u njima sadržani. Naš je prijedlog dati tvrtki primjerenu opciju praćenja troškova kvalitete i njihova sustavnog vrednovanja.*

Ključne riječi: *kvaliteta, kontroling u kvaliteti, troškovi kvalitete, izvještavanje*

1 INTRODUCTION
1. UVOD

Accountancy plays a vital role in the company. It is a source of information for a number of entities the entrepreneur comes into contact with by conducting its business. Owners, managers, investors, banks, insurance companies, unions and creditors are always interested only in a particular area of results or in complex results of a company performance for a calendar period. Instead, they should be provided with high-quality information to be able to get a comprehensive picture of the company position.

All tasks, to be fulfilled by accountancy in a company, can only be carried out successfully if attention is paid not only to the financial accounting, but also to

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cost accounting, which focuses on internal processes. For a successful company management in the market environment, such information is necessary for successful control. This paper confirms the need of high-quality economy, implying monitoring of quality costs as part of quality control. The current business environment requires speed, flexibility and quality. According to Šatanová *et al*. (2010) it is necessary to realize the fact that without good quality financial and economic management, a company can hardly stand the pressure of everyday competition.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

This paper presents the structure, status and role of accounting in Slovakia. Further, the application is presented of accounting and quality economy to quality control. Based on information obtained from the available literature, methodology and implementation of procedures for quality control have been proposed and applied to management of specific business processes. In the proposed solution, the selected models of quality costs have been applied, namely PAF model, where quality costs in defined cost types have been monitored. By using control procedure, it is recommended to compile quarterly, half annual and annual summary reports that are an important source for rational and effective company management. Results are presented in graphical form using MS Excel.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Accounting in a company - its role and tasks
3.1. Obračunavanje u tvrtki – uloga i zadaća

Each company in Slovakia is run in accordance with the Accounting Law No. 431/2002 and has an obligation to keep records of its activities related to the area of financial accounting. This area gives a picture of the company management, and its results are mainly used to provide information to external users in terms of profit and loss account, balance sheet and cash flow statement. For managing and further decision making about the direction of the company, such information does not provide sufficient explanatory power and is also available to potential competitors. For this reason, companies promoted the introduction of the so-called cost accounting, which deals with the economic fundamentals of the internal point of view. It presents a picture of the company management, its position and it is only for internal users who use the results obtained for the company management.

3.2 Economy and quality control
3.2. Kontroling u ekonomici i kvaliteti

Economy quality also monitors a special category of expenses called quality costs, which represent a financial outlay required for the activities associated with providing, maintaining and improving quality. It is an economic category used to evaluate the effectiveness and efficiency of processes, and the quality impact on the creation of profit, costs structure, output, income and sales. The quality costs provide information concerning the implementation of quality control system in the company, determine the optimal level of product quality or service and show the weaknesses of the company.

The quality costs are extremely imortant for management decision making and it is therefore necessary to introduce them in the company system of monitoring and evaluation. Figure 1 represents schematically the process of the system development.

Each company constantly tries to improve its business. For this reason companies try to implement and use new advanced knowledge in magement. Control is definitely one of them, and it has become an indispensable part of modern business management. According to Macík (1999) controlling is the "tool for integrating multiple information systems and management, including strategic and operational planning, accounting - particularly financial and internal (operational costs), budgets, costing and other forms of evidence and reporting". Quality cost reporting system is the basis of business of budget-type companies (Potkány, 2009). Information from corporate reporting can be used for establishing intradepartmental prices (Potkány, 2005). The concept of quality control is obtained by connecting the area of quality with controling, and however it is not widespread nor applied in Slovakia. Currently, the concept of quality control is process-orientated, not product-orientated, as in practice the concept of ISO standards and TQM promote just a procedural approach. One of the objectives of quality control is also to improve the overall quality of the company. In quality management, control involves several tasks: (a) it coordinates the business areas, (b) promotes quality management and (c) monitors and reviews performance measures by the provision of appropriate information. For this purpose several tools are used such as calculation of quality costs, quality indicators and quality of reporting.

3.3 Quality control and reporting
3.3. Kontrola kvalitete i izvještavanje

The actual application of the concept of quality control management to business processes can be divided into several stages.

In the first phase the state of the company is analyzed. Its quality objectives and processes are identified, and then classified. The goals themselves must be part of an overall strategic goal and future direction of the company. The idea is to maximize the measurable objectives and therefore quality should be a measurable value in the company, as the basic feature of quality control. The individual targets should be specified not only at the company level but also at the level of departments and workplaces. This process results in the specification of targets for the quality of the company (see Tab. 1).

After specifying the quality objectives, the main groups of quality costs were identified, taking into account the specific situation in the company. In our case,

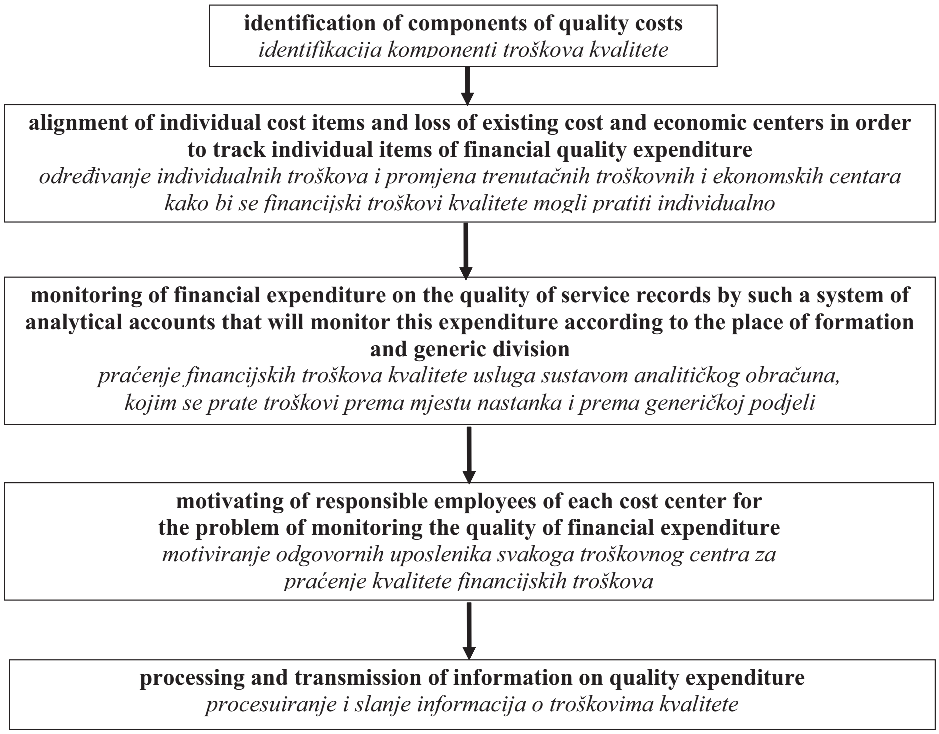

Figure 1 Building a system of monitoring and evaluation of costs (Šatanová *et al*., 2008)
Slika 1. Izgradnja sustava praćenja i vrednovanja troškova (Šatanová i sur., 2008)

the cost items in Table 2 will be subject to observation, and their distribution will be made according to the PAF model, which implies the division of quality costs to prevention costs, evaluation costs, and internal and external losses.

To see clearly the total quality costs, the use of MS Excel was recommended. With MS Excel the data would be processed in prepared workbooks. Every workbook also had to include sub-reports on the quality costs. These sub-reports would be checked monthly.

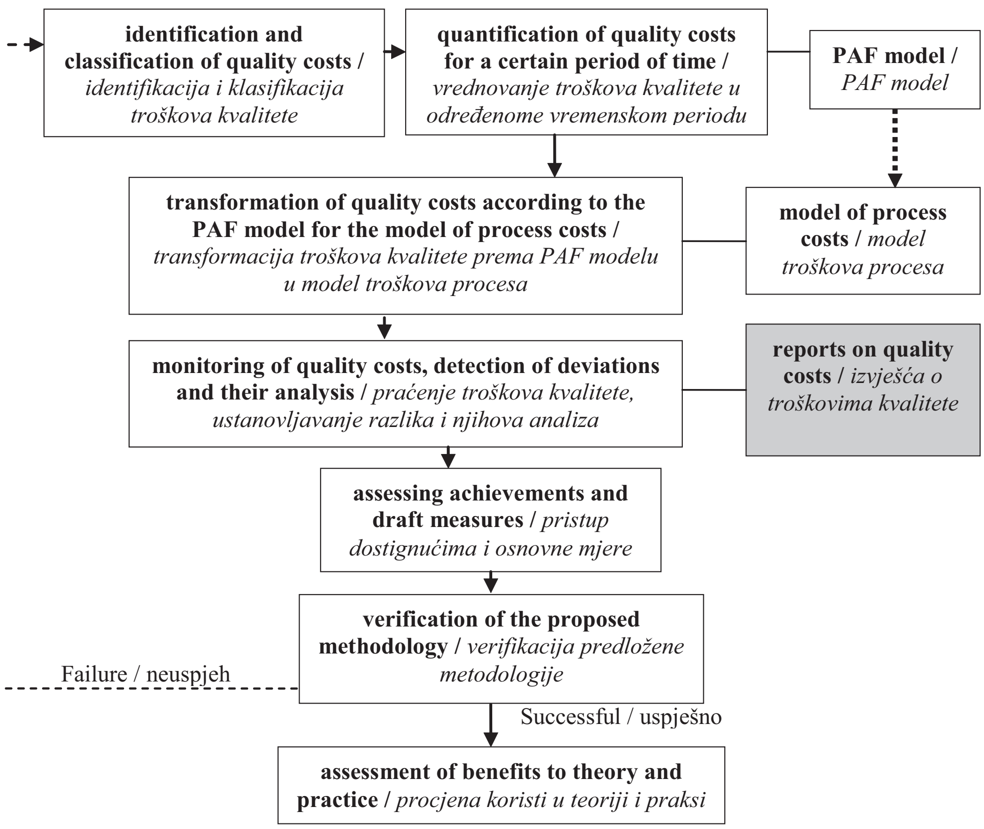

Figure 2 Methodology of the concept of quality control (Šatanová *et al*., 2008)
Slika 2. Metodologija i koncept kontrolinga kvalitete (Šatanová i sur., 2008)

Table 1 Specification of quality targets (Šatanová *et al.*, 2008)
Tablica 1 Specifikacija ciljeva kvalitete (Šatanová i sur., 2008)

No.	**Basic objectives (Company level)** *Osnovni ciljevi (razina tvrtke)*	No.	**Auxiliary objectives (Dep. level)** *Pomoćni ciljevi (razina odjela)*	**Dep.** *Odjel*	No.	**Auxiliary objectives (Workplace level)** *Pomoćni ciljevi (razina radnog mjesta)*	**Responsible person** *Odgovorna osoba*
1.	Identification of business processes *Identifikacija poslovnih procesa*	1.1	Map compilation processes *Mapa skupine procesa*	Department of quality management (DQM) – Quality Manager *Odjel upravljanja kvalitetom (DQM) – Menadžer kvalitete*			
2.	Claims Overview *Pregled zahtjeva*	2.1	Monitoring the number of claims *Praćenje brojnih zahtjeva*	DQM		Claims received from customers *Zahtjevi zaprimljeni od kupaca*	Quality Manager *Menadžer kvalitete*
				Sales depart-ment / *Odjel prodaje (SD)*		Claims addressed to suppliers / *Zahtjevi upućeni dobavljaču*	Manager of SD *Menadžer prodaje*
		2.2	Evaluation of the ratio of claims to goods *Vrednovanje udjela zahtjeva u dobru*	DQM		Accepted claims for invoiced goods *Prihvaćeni zahtjevi naplaćenih dobara*	Quality Manager *Menadžer kvalitete*
				SD		Accepted claims for goods ordered, with respect to the material *Prihvaćeni zahtjevi naručenih dobara, do materijala*	Manager of SD *Menadžer prodaje*
3.	Production efficiency *Efikasnost proizvodnje*	3.1	Monitoring of control points (check) *Praćenje kontrolnih točaka*	DQM		Final control – accor-ding to the control points / *Završna kontrola prema kontrolnim točkama*	Quality Manager *Menadžer kvalitete*
		3.2	Multiple errors *Višestruke pogreške*	DQM		- for production section *- za proizvodni dio*	Quality Manager *Menadžer kvalitete*
		3.3	Nonconforming products *Neprihvatljivi proizvodi*	Manufacturing department *Proizvodni odjel (MD)*		- for machines *- za strojeve*	Manager of MD *Menadžer proizvodnog odjela*
		3.4	Productivity *Produktivnost*	MD		Manufacture of furniture *Proizvodnja namještaja*	Manager of MD *Menadžer proizvodnog odjela*
						Production of battenboard *Proizvodnja ploča*	Manager of MD *Menadžer prozvodnog odjela*
4.	Education and training of employees *Edukacija i trening uposlenih*	4.1	Training plan *Plan izobrazbe*	Personal departement / *Odjel kadrova (PD)*		Internal training *Interna izobrazba*	Manager of PD *Menadžer odjela kadrova*
						External training *Vanjska izobrazba*	Manager of PD *Menadžer odjela kadrova*
5.	Quality evaluation *Vrednovanje kvalitete*	5.1	Internal audits *Interni auditi*	DQM – Quality Manager / *Menadžer kvalitete*			
		5.2	External audits *Vanjski auditi*	DQM – Quality Manager / *Menadžer kvalitete*			

Consequently, quarterly, and if necessary, half annual and annual summary reports about the quality costs would be compiled.

Effective control of economy in quality assurance will be implemented through a system of quality indicators. It provides the necessary information concerning the behavior of quality costs. It is a combination of cost and performance parameters. The cost consists of the so-called ratios of different groups of quality costs.

For the purpose of quality control the most important elements are:

- an indicator of the proportion of internal losses to total operating costs

Table 2 Group quality costs (Šatanová *et al.*, 2008)
Tablica 2 Skupine troškova kvalitete (Šatanová *et al.*, 2008)

Code / Kod	Type of quality costs / *Tip troškova kvalitete*	Content Items / *Sadržaj*
N 1	**Prevention costs** / Troškovi prevencije	
N 1.1	Costs for the selection, approval and evaluation of suppliers *Troškovi određivanja, odobrenja i vrednovanja dobavljača*	Total expenditure for the specification of the quality of supply *Potpuni troškovi specifikacije kvalitete dobavljača*
N 1.2	Costs of internal audits *Troškovi internog audita*	Salaries and overhead costs for regular audits initiated by senior management / *Plaće i drugi troškovi za redoviti audit potaknut od vrhovnog menadžmenta*
N 1.3	The cost of external audits *Troškovi vanjskog audita*	The amount invoiced by the audit point / *Visina računa po točkama audita*
N 1.4	Internal costs for training and education of employees / *Interni troškovi izobrazbe i treninga uposlenika*	Staff costs and overheads. / *Troškovi osoblja i drugi troškovi*
N 1.5	External costs for training and education of employees / *Vanjski troškovi izobrazbe i treninga uposlenika*	The amount invoiced by an educational organization (seminars, courses, post-secondary studies, internships, etc.) / *Iznos računa prema edukacijskoj razini (seminari, tečajevi, poststudiji, stažiranje i sl.)*
N 1.6	The cost of calibration services *Troškovi usluga uravnoteženja*	The amount invoiced by an external organization *Iznos računa vanjske organizacije*
N 2	**Costs of evaluation /** *Troškovi vrednovanja*	
N 2.1	Cost of check-in control *Troškovi kontrole ulaza*	Material, labor and overhead costs of physical access control inputs, auxiliary materials, chemical analysis and so on / *Materijal, rad i drugi troškovi fizičke kontrole ulaza, pomoćnih materijala, kemijske analize i sl.*
N 2.2	Costs of production control *Troškovi kontrole proizvodnje*	Material, labor and overhead costs of production control *Materijal, rad i drugi troškovi kontrole proizvodnje*
N 2.3	Costs of checkout control *Troškovi kontrole izlaza*	Material, labor and overhead costs of the final inspection *Materijal, rad i drugi troškovi završne kontrole*
N 2.4	Costs of internal laboratory tests *Troškovi internog testiranja u laboratoriju*	Total operating costs of laboratory processes that ensure verification of product compliance / Ukupni operativni troškovi laboratorijskog procesa kako bi se osigurala potvrda kvalitete proizvoda
N 2.5	Costs for external laboratory tests *Troškovi vanjskog laboratorija*	The amount invoiced by an external organization / *Ukupni iznos računa vanjske organizacije*
N 2.6	Costs for the purchase and maintenance of measuring devices / *Troškovi nabave i održavanja mjernih uređaja*	One-off investment and operating costs, including costs of repairs for all types of measuring devices in the company / *Jednokratna investicija i operativni troškovi, uključujući troškove popravaka svih mjernih uređaja u tvrtki*
N 3	**Internal losses** / Interni troškovi	
N 3.1	The cost of multiple errors *Troškovi višestrukihpo grešaka*	Materials, labor, overhead costs incurred due to improperly adjusted equipment / *Materijal, rad i drugi troškovi nastali zbog loše pripremljene opreme*
N 3.2	The costs of additional work to repair repairable nonconforming products (rejects) / *Troškovi dodatnog rada za popravak nekvalitetnih proizvoda (odbijeni)*	Cost of avoidable differences in semi-materials, materials and products i.e. direct labor, direct material and the corresponding part of overheads *Troškovi mogućih izbjegavanja grešaka u poluproizvodima, materijalima i proizvodima, tj. izravni rad, izravni materijal i pripadajući dijelovi kao dodatni troškovi*
N 3.3	Irreparable loss of nonconforming products (rejects) / *Nepopravljivi gubici zbog nekvalitetnih proizvoda*	The value of nonconforming materials, semi-materials and products, which must be banned from further use / *Vrijednost materijala, poluproizvoda i nekvalitetnih proizvoda koji se moraju isključiti iz daljnje uporabe*
N 3.4	Unreclaimed losses from supply differences / *Neobračunani troškovi razlika u specifikaciji dobavljača*	The value of unserviceable and unreclaimed nonalready purchased material inputs, differences not caused by the manufacturer *Vrijednost nepopravljivoga i neobračunanoga nabavljenog materijala, razlike koje nisu uzrokovane proizvodnjom*
N 4	**External losses /** *Vanjski troškovi*	
N 4.1	The cost of nonconforming unrepairable products (claims) / *Troškovi nekvalitetnih nepopravljivih proizvoda (zahtjevi)*	The value of external differences / *Vrijednost vanjskih promjena*
N 4.2	Discount prices of products of substandard quality / *Snižena cijena zbog nedovoljne razine kvalitete*	Loss difference between the normal selling price and the discounted price *Gubici zbog razlike između normalne prodajne cijene i snižene cijene*
N 4.3	Transport costs caused by nonconforming products / *Troškovi transporta zbog nekvalitetnih proizvoda*	Transport, labor costs for handling external differences *Transport, troškovi rada zbog rukovanja nekvalitetnim proizvodom u uporabi*
N 4.4	Travelling costs due to nonconforming products / *Troškovi puta zbog nekvalitetnih proizvoda*	Travelling costs for handling of external differences *Putni troškovi zbog rukovanja nekvalitetnim proizvodom u uporabi*

Table 3 Quality cost report (Šatanová *et al*., 2008)
Tablica 3 Izvješće o troškovima kvalitete (Šatanová i sur., 2008)

Quality cost report / *Izvješće o troškovima kvalitete*															
Code *Kod*	**Cost item** *Trošak*	**Reporting period (month)** / *Razdoblje izvještavanja (mjesec)*							**Cumulative** / *Kumulativno*						
		Plan *Plan*		Recalcul. Plan *Preračunani plan*		Reality *Real-nost*		Deviati-on *Razlike*	Plan *Plan*		Recalcul. Plan *Prera čuna-ni plan*		Reality *Real-nost*		Deviati-on *Razlike*
		€	%	€	%	€	%		€	%	€	%	€	%	
N 1	Prevention costs / *Troškovi preventive*														
N 1.2	Internal audits / *Interni audit*														
N 1.3	External audits / *Vanjski audit*														
N 1.4	Internal education and training of employees / *Interna edukacija i trening uposlenih*														
N 1.5	Education and training of employeess Externally / *Vanjska edukacija i trening uposlenih*														
N 1.6	Calibration services *Usluge uravnoteženja*														
Total / *Ukupno*															
N 2	Evaluation costs / *Troškovi vrednovanja*														
N 2.1	Check-in control / *Ulazna kontrola*														
N 2.2	Production control *Kontrola proizvodnje*														
N 2.3	Checkout control / *Izlazna kontrola*														
N 2.4	Internal laborat. tests *Interni laboratorijski testovi*														
N 2.5	Externé laborat. tests *Vanjski laboratorijski testovi*														
N 2.6	Purchase and maintenance of measuring devices / *Nabava i održavanje mjernih uređaja*														
Total / *Ukupno*															
N 3	Internal losses / *Interni gubici*														
N 3.1	Multiple errors / *Višestruke pogreške*														
N 3.2	Extra work to repair repairable nonconforming products *Dodatni rad radi popravka nekvalitetnih proizvoda*														
N 3.3	Losses from unrepairable nonconf. products / *Gubici zbog nepopravljivih proizvoda*														
N 3.4	Un-reclaimed losses of delivered rejects / *Nezahtijevani troškovi isporuke odbijenih proizvoda*														
Total / *Ukupno*															
N 4	External losses / *Vanjski troškovi*														
N 4.1	Nonconf. repairable products (claims) *Nekvalitetni popravljivi proizvodi (zahtjevi)*														
N 4.2	Discount prices of products of substandard quality *Niže cijene zbog loše kvalitete*														
N 4.3	Transport induced by nonconf. products / *Transport uzrokovan nekvalitetnim proizvodima*														
N 4.4	Travel due to nonconf. products Putni troškovi zbog nekvalitetnih proizvoda														
Total / *Ukupno*															
Total quality costs / *Ukupni troškovi kvalitete*															

- an indicator of the proportion of external losses to total cost
- an indicator of the proportion of external losses to the turnover of company
- an indicator of the costs for the evaluation phase supply to the total purchase cost of materials
- an indicator of the proportion of operating costs for the evaluation of the total operating costs
- an indicator of total variable quality costs to the overall business costs and other

Based on the results obtained from the reports and parameter values, the benefits will reveal themselves arising from the applied methodology of the concept of quality control. The top management will then be informed about their performance in terms of quality and future measures necessary for ensuring and improving quality will be formulated.

The whole concept of the methodology of quality control can be summarized in the scheme below (see Fig. 2).

Verification is the final stage of the methodology of the concept of quality control (see Figure 2) and provides successful implementation of quality control in practice. In this way, the company has the possibility to detect and subsequently eliminate the shortfalls, thus leading to improvements in the quality of business processes and increasing overall efficiency.

4 CONCLUSION
4. ZAKLJUČAK

As companies seek to establish and implement a quality management system on their own terms, a system of monitoring and evaluating quality costs should be built in each of them. It should be noted, however, that ISO 9000 standards do not track quality costs, nor financial indicators or measurements. It is at the discretion of the company to decide whether and how to pay attention to this area. However, the fact remains that business sphere does not deal much with the given indicators and their monitoring, and that this analysis is significantly underestimated. Companies usually solve the problem of reducing costs only when dealing with the actual cost and with the related expenses. We have offered to companies an option to track their quality costs and subsequently to evaluate them. In this way, the possibility is provided of tracking the effects of quality costs. First, there are losses due to shortcomings in the field of quality assurance. However, there is also the opportunity to identify any significant effects on corporate performance, and the possibility of reducing the total costs of some performance indicators and quality management systems. It is possible to quantify any positive benefits either in production or in the user domain. Finally, it may create a basis for pricing the product or service that will take into account the quality taking into consideration producer and user benefits.

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Neka fizikalna i mehanička svojstva drva šljive (*Prunus Domestica* L.)

Some Physical and Mechanical Properties of Plum Tree (*Prunus Domestica* L.)

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SAŽETAK • *Šljiva (Prunus domestica L.) jedna je od najrasprostranjenijih voćkarica na području jugoistočne Europe. Zbog svojih plodova kultivira se već stoljećima. S pojavom virusne bolesti šarke odumro je velik broj starih sorti šljive. Za suzbijanje šarke ne postoji nikakvo kemijsko sredstvo već je jedini način sprečavanja širenja te bolesti rušenje cijelih nasada. Zato se pojavljuju velike količine drvne sirovine koja se može iskoristiti u industrijske svrhe. U Hrvatskoj smo posljednjih godina svjedoci tog procesa, koji se polako širi na područje Bosne i Hercegovine i ostalih zemalja u regiji. U ovom su radu ispitana neka fizikalna i mehanička svojstava drva šljive s lokaliteta srednje Bosne i Hercegovine (Gornji Vakuf - Uskoplje). Rezultati tog ispitivanja mogu pomoći pri određivanju tehnoloških svojstava drva šljive. Od fizikalnih svojstava ispitana je gustoća drva šljive u apsolutno suhom stanju, nominalna gustoća, maksimalno utezanje u longitudinalnome, radijalnome i tangencijalnom smjeru te maksimalno volumno utezanje. Od mehaničkih svojstava ispitana je čvrstoća na vlak paralelno s vlakancima. Od makroskopskih karakteristika mjerena je širina goda radi korelacije s izmjerenim fizikalnim i mehaničkim svojstvima drva šljive. Srednja vrijednost gustoće šljivina drva u apsolutno suhom stanju iznosi 0,705 g/cm³, a srednja vrijednost nominalne gustoće iznosi 0,619 g/cm³. Srednja vrijednost maksimalnog utezanja u longitudinalnom smjeru je 0,3 %, u radijalnom smjeru 4,8 %, u tangencijalnom smjeru 7,5 %, a srednja vrijednost maksimalnoga volumnog utezanja iznosi 12,1 %. Srednja vrijednost čvrstoće na vlak paralelno s vlakancima pri 12 % -tnom sadržaju vode jest 101,9 MPa.*

Ključne riječi: šljiva (Prunus domestica L.), šarka šljive, fizikalna i mehanička svojstva drva šljive, makroskopske karakteristike.

ABSTRACT • *Plum (Prunus domestica L.) is one of the most widespread species of fruit trees in South-East Europe. Because of its fruits, it has been cultivated for centuries. The emergence of plum pox virus caused the disappearance of a large number of „old" plum sorts. There is no chemical agent to combat plum pox virus, and the only way to prevent the spread of the virus is to destroy plantations. For this reason there is a large amount of wood mass that can be used for industrial purposes. In Croatia, over the past years we have witnessed this process that slowly spreads along the territory of Bosnia and Herzegovina and other countries in the region. In this research some physical and mechanical properties were studied of plum wood from middle Bosnia and Herzegovina. The results of this research can be used to determine technological properties of plum wood. The physical properties of plum wood that were studied are as follows: density in absolutely dry condition, nominal density, total longitudinal, radial, tangential and volumetric shrinkage. The mechanical property of plum wood that was studied is: ultimate tensile stress parallel to the grain. From macroscopic characteristics, growth ring was measured for the*

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correlation with the studied physical and mechanical properties of plum wood. Mean density in absolutely dry condition is 0.705 g/cm³, and mean value of conventional density is 0.619 g/cm³. Mean value of the total longitudinal shrinkage is 0.3 %, total radial shrinkage is 4.8 %, total tangential shrinkage is 7.5 %, and mean value of the total volumetric shrinkage is 12.1 %. Mean value of the ultimate tensile stress parallel to the grain at 12 % water content is 101.9 MPa.

Key words: *plum wood (Prunus domestica L.), plum pox virus, physical and mechanical properties of plum wood, macroscopic characteristics.*

1. UVOD
1 INTRODUCTION

Danas gotovo da ne postoji vrsta drva koja se ne obrađuje i iskorištava za određenu namjenu, i to zbog svojih estetskih, fizikalnih, mehaničkih ili nekih drugih svojstava. Tako se u upotrebi i preradi sve više pojavljuju i koriste voćkarice, najčešće trešnja, orah, kruška, jabuka, maslina, šljiva i dr. Zato je važno ispitati i odrediti neka fizikalna i mehanička svojstva tih vrsta drva koja će biti korisna za daljnju obradu i upotrebu tog drva kao materijala. Šljivovina se kao materijal malo upotrebljava, često zbog nedovoljnog poznavanja kvaliteta koje ima, tako da male, ali vrijedne količine drva koje nastaju najčešće sječom stabala radi pomlađivanja voćnjaka uglavnom završe kao ogrjevno drvo.

Poznavanje tehnoloških svojstava drva važan je preduvjet za racionalno iskorištava drvne sirovine. Za tehnološka svojstva pojedine vrste drva važna su njegova anatomska, kemijska, fizikalna i mehanička svojstva.

Ovo je istraživanje provedeno s ciljem definiranja i upotpunjavanja spoznaja o nekim fizikalnim i mehaničkim svojstvima šljivovine radi daljnjih i potpunijih određivanja njezinih tehnoloških svojstava. U ovom su istraživanju od fizikalnih svojstava ispitivane gustoća u apsolutno suhom stanju, nominalna gustoća, maksimalno longitudinalno, radijalno, tangencijalno i volumno utezanje. Od mehaničkih svojstava ispitana je čvrstoća na vlak paralelno s vlakancima. Od makroskopskih svojstava izmjerena je širina goda.

Ispitivanja su provedena u laboratoriju Zavoda za znanost o drvu Šumarskog fakulteta u Zagrebu.

2 MATERIJAL I METODE
2. MATERIAL AND METHODS

Šljiva (*Prunus domestica* L.) drvo je botaničkog reda *Rosales* iz porodice *Rosaceae.* Među koštičavim voćem šljiva je najrasprostranjenija voćna vrsta. Podrijetlo šljive je nepoznato (Herman, 1971). Vjerojatno je hibrid, možda između crnotrne prunike (*Prunus spinosa* Forssk.) i mirobalanine prunike (*Prunus cerasifera* Ehrh.). Obje vrste potječu s Kavkaza, a poznati hibridi na tom se području pojavljuju prirodno (Russell i Cutler, 2004). Stablo naraste do 10 m visine i promjera debla do 0,7 m (Wagenführ, 2007). Životna dob šljive je duga. Bjeljika je žućkaste boje, dok je srž crvenkastosmeđe do ljubičastosmeđe boje. Prema rasporedu pora, šljivovina pripada sitnoprstenasto poroznim vrstama drva. U početnoj zoni goda pore su brojnije i gušće, obično i nešto veće od pora u kasnijem dijelu goda. Takav raspored pora uvjetuje porozniju i svjetliju početnu zonu goda, koja se dobro vidi običnim okom, iako se pojedinačne pore ne mogu uočiti (Špoljarić, 1978). Makroskopska struktura poprečnoga, radijalnoga i tangencijalnog presjeka šljivovine prikazana je na slici 1. (autor slika je Sedlar, T.). Drvo šljive je tvrdo i žilavo, dobro se mehanički obrađuje i dobro se premazuje, stoga je prikladno za izradu puhačih instrumenata i trupova za tamburice. Upotrebljava u tokarstvu, za izradu različitih proizvoda, a jedan od poznatijih je slavina za vinsku burad. Od šljivovine se proizvodi furnir, dijelovi namještaja, ali i cjeloviti namještaj, uglavnom za sjedenje (Wagenführ, 2007). Zbog svoje specifične i nepravilne teksture iskorištava se za proizvodnju egzotičnog namještaja, kao i za izradu intarzija.

a) b) c)

Slika 1. Drvo šljive: a) poprečni presjek, b) radijalni presjek, c) tangencijalni presjek
Figure 1 Wood of *Prunus domestica* L. a) cross section, b) radial section, c) tangential section

Ispitno stablo za potrebe istraživanja odabrano je prema odredbama norme ISO 3129 iz 1975. godine. Stablo šljive za ovo istraživanje dopremljeno je iz mjesta Uskoplja, u Bosni i Hercegovini. Na ispitnom su stablu prikupljeni svi relevantni parametri: geografski položaj, prsni promjer, tlocrtna projekcija krošnje, orijentiranost stabla prema stranama svijeta, ukupna visina stabla, visina do prve žive grane i visina panja. Iz ispitnog stabla izrađen je ispitni trupčić približne duljine 80 cm, s početkom na prsnoj visini. Ispitni je trupčić raspiljen na srednjaču od koje su izrađeni uzorci za određivanje nekih fizikalnih i mehaničkih svojstava šljivovine. Prema važećim normama ISO 3131 iz 1975 godine, obavljeno je određivanje makroskopskih svojstava i gustoće šljivovine, a prema normama ISO 4469 iz 1981. i ISO 4858 iz 1982. godine, obavljeno je određivanje longitudinalnoga, radijalnoga, tangencijalnoga i volumnog utezanja. Određivana je gustoća u apsolutno suhom stanju, kao i nominalna gustoća. Od makroskopskih obilježja mjerena je širina goda na svakom uzorku radi usporedbe s izmjerenim fizikalnim i mehaničkim svojstvima. Prema odredbama norme ISO 3345 iz 1975. godine, izrađeni su uzorci i određena je čvrstoća na vlak paralelno s vlakancima.

Statistička obrada podataka sadržava prikaz broja izmjerenih uzoraka (n), minimalnu (min.), srednju (aver) i maksimalnu (maks.) vrijednost određenih svojstava te njihovu standardnu devijaciju (stdev) i varijancu (var).

3. REZULTATI ISTRAŽIVANJA
3 RESULTS OF RESEARCH

3.1. Fizikalna svojstva
3.1 Physical properties

U tablici 1. prikazane su statističke vrijednosti odabranih fizikalnih svojstava šljivovine.

Zbog rasipanja rezultata na slici 2. dobiven je relativno mali koeficijent korelacije koji iznosi R^2 = 0,205. Usprkos tome, vidljiv je blagi trend porasta gustoće u apsolutno suhom stanju s povećanjem širine goda.

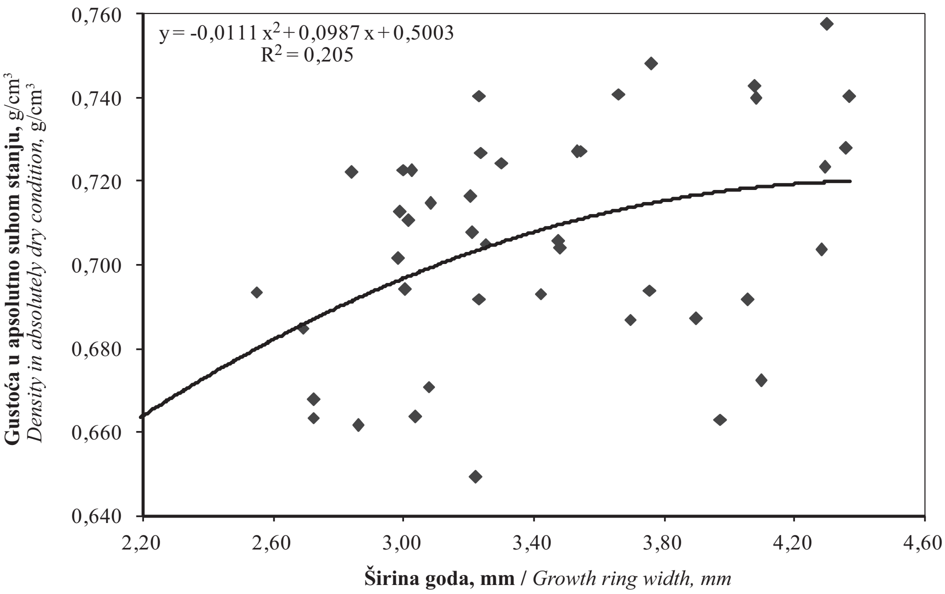
Tablica 1. Pregled statističkih vrijednosti gustoće u apsolutno suhom stanju, nominalne gustoće, maksimalnoga longitudinalnog, radijalnoga, tangencijalnoga i volumnog utezanja ispitivane šljivovine
Table 1 Survey of statistical values of density in absolutely dry condition, conventional density, total longitudinal, radial, tangential and volume shrinkage of plum wood studied

	ρ_0 g/cm³	ρ_y g/cm³	β_{lmax} %	β_{rmax} %	β_{tmax} %	β_{vmax} %
N	44	44	33	44	44	44
MIN	0,649	0,564	0,0	2,7	3,5	9,3
AVE	0,705	0,619	0,3	4,8	7,5	12,1
MAX	0,758	0,655	1,0	10,3	11,4	15,0
SD	0,0278	0,0212	0,235	1,833	1,737	1,379
VAR	0,0008	0,0004	0,055	3,359	3,017	1,900

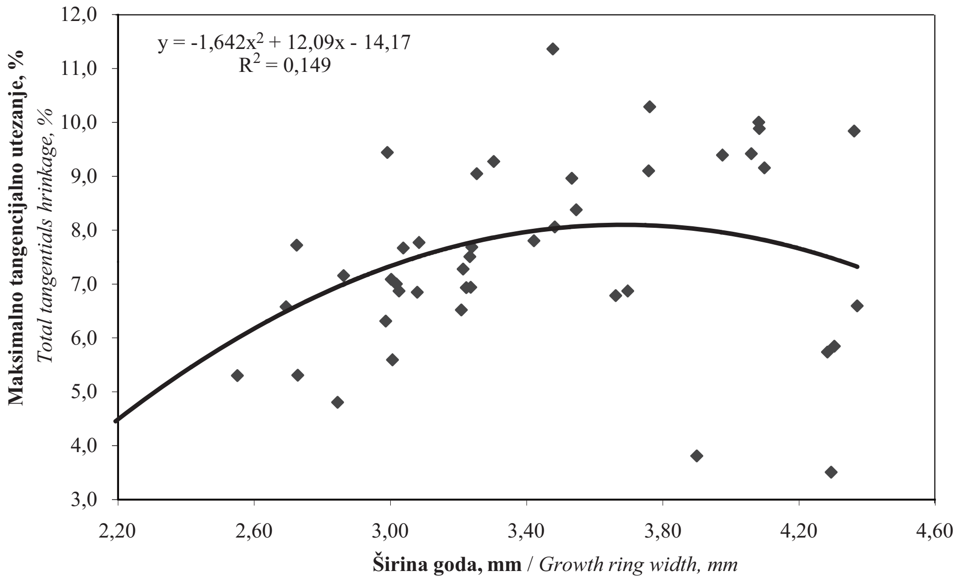
Legenda: ρ_0 – gustoća u apsolutno suhom stanju, ρ_y – nominalna gustoća, β_{lmax} – maksimalno longitudinalno utezanje, β_{rmax} – maksimalno radijalno utezanje, β_{tmax} – maksimalno tangencijalno utezanje i β_{vmax} – maksimalno volumno utezanje
Legend: ρ_0 – density in absolutely dry condition, ρ_y – conventional density, β_{lmax} – total longitudinal shrinkage, β_{rmax} – total radial shrinkage, β_{tmax} – total tangential shrinkage and β_{vmax} – total volumetric shrinkage

Na slici 3. vidljiv je blagi porast maksimalnoga tangencijalnog utezanja šljivovine s povećanjem širine goda. Zbog rasipanja srednjih vrijednosti tangencijalnog utezanja, pogotovo u širim godovima (3,8 mm naviše), taj je trend smanjen, pa je stoga i koeficijent korelacije smanjen i iznosi R^2 = 0,1495. Slika 4. prikazuje odnos maksimalnoga volumnog utezanja i širine goda. Iz slike je vidljivo da maksimalno volumno utezanje također raste s povećanjem širine goda, što nam potvrđuje i koeficijent korelacije R^2 = 0,41.

Iz dobivenih vrijednosti utezanja u tablici 1. možemo zaključiti da je šljivovina dimenzijski srednje stabilna vrsta drva (Ugrenović, 1950).



Slika 2. Odnos gustoće u apsolutno suhom stanju i širine goda šljivovine.
Figure 2 Relationship between density in absolutely dry condition and growth ring for plum wood



Slika 3. Odnos maksimalnoga tangencijalnog utezanja i širine goda šljivovine.
Figure 3 Relationship between total tangential shrinkage and growth ring for plum wood

3.2. Mehanička svojstva
3.2 Mechanical properties

U tablici 2. prikazane su statističke vrijednosti čvrstoće šljivovine na vlak paralelno s vlakancima.

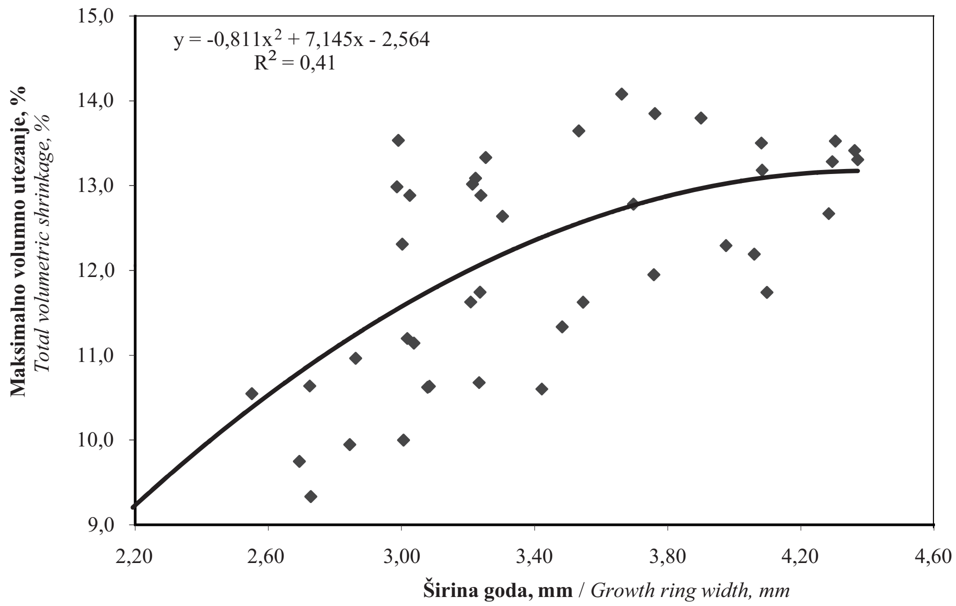
Slika 5. prikazuje ovisnost čvrstoće na vlak paralelno s vlakancima o širini goda. Na slici je vidljivo veliko rasipanje rezultata te je iz krivulje nemoguće utvrditi postoji li povezanost između čvrstoće na vlak paralelno s vlakancima i širine goda. To je također vidljivo iz malog koeficijenta korelacije $R^2 = 0{,}0689$.

Iz tablice je vidljivo da srednja vrijednost čvrstoće na vlak paralelno s vlakancima pri 12 % -tnom sadržaju vode iznosi 101,9 MPa, što šljivovicu svrstava u vrste drva sa srednje velikim otporom na vlačna naprezanja paralelno s vlakancima (Ugrenović, 1950).

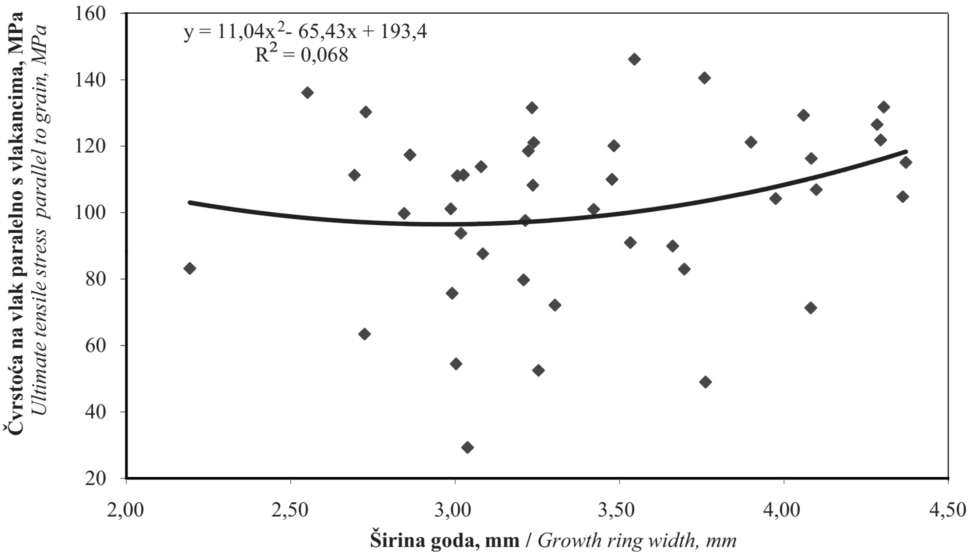
Tablica 2. Pregled statističkih vrijednosti čvrstoće šljivovine ispitivane na vlak paralelno s vlakancima.
Table 2 Survey of statistical values of ultimate tensile stress parallel to the grain of plum wood studied

Statistička vrijednost *Statistical value*	$\sigma_{12\%}$ MPa
N	44
MIN.	29,3
AVER	101,9
MAKS.	146,2
STDEV	26,41
VAR	697,34

Legenda: $\sigma_{12\%}$ – čvrstoća na vlak paralelno s vlakancima / *Legend:* $\sigma_{12\%}$ – *ultimate tensile stress parallel to the grain*



Slika 4. Odnos maksimalnoga volumnog utezanja i širine goda šljivovine.
Figure 4 Relationship between total volumetric shrinkage and growth ring for plum wood



Slika 5. Odnos čvrstoće na vlak paralelno s vlakancima i širine goda šljivovine
Figure 5 Relationship between ultimate tensile stress parallel to the grain and growth ring for plum wood

Zbog anizotropnosti i nehomogenosti drva (Horvat i Krpan, 1967) kao materijala, očekivano je da postoje razlike u čvrstoći na vlak, ne samo između vrsta drva već i u samom poprečnom presjeku unutar iste vrste drva. Zato je i varijabilnost rezultata maksimalne vlačne čvrstoće šljivovine toliko velika.

4. ZAKLJUČCI
4 CONCLUSIONS

Na temelju ispitivanja i mjerenja obavljenih na drvu šljive (*Prunus domestica* L.) te analizom dobivenih podataka ustanovljena je srednja vrijednost gustoće drva šljive u apsolutno suhom stanju od 0,705 g/cm^3. Srednja vrijednost nominalne gustoće je 0,619 g/cm^3, srednja vrijednost maksimalnog utezanja u longitudinalnom smjeru 0,3 %, u radijalnom smjeru 4,8 %, u tangencijalnom smjeru 7,5 %, a srednja vrijednost maksimalnoga volumnog utezanja iznosi 12,1 %. Srednja vrijednost čvrstoće na vlak paralelno s vlakancima pri 12 % -tnom sadržaju vode iznosi 101,9 MPa.

Drvo i drvna sirovina prirodno su obnovljivi materijali, ali to nam ne daje pravo da nerazumno iskorištavamo kvalitetnu drvnu građu. Iako su trupci šljive uglavnom malog promjera, taj se nedostatak može kompenzirati većom količinom sirovine. Zbog iznimne teksture od šljivovine se može proizvoditi ekskluzivan namještaj ili neki drugi proizvodi koji će se prodavati po visokoj cijeni, čime će taj cijeli proizvodni ciklus biti financijski isplativ.

5. LITERATURA
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Međunarodna asocijacija za ekonomiku i menadžment u preradi drva i proizvodnji namještaja WoodEMA, i.a. je međunarodna, nepolitička, neprofitabilna i otvorena asocijacija.
Cilj asocijacije je da promovira znanost te znanstvena i stručna dostignuća njezinih članova, omogući međusobnu znanstvenu suradnju kao i da podupre znanstveni i stručni razvoj unutar njezina područja djelovanja.
Kako bi se postigli ti ciljevi, asocijacija se bavi sljedećim aktivnostima:

- Razmjenom znanja i rezultata istraživanja među članovima organiziranjem savjetovanja i publiciranjem članaka u časopisima i zbornicima radova
- Potporom zajedničkoj znanstvenoj suradnji među članovima asocijacije kroz elaborate i znanstvene projekte
- Potporom razvoju znanstvenih i stručnih organizacija u području djelovanja asocijacije
- Znanstvenom i stručnom edukacijom organiziranjem znanstvenih i stručnih simpozija i savjetovanja
- Prikupljanjem i razmjenom tržišnih, tehnoloških i tehničkih podataka

Članovi iz mnogih Europskih zemalja i SAD pozivaju Vas da nam se pridružite.
Sve informacije možete dobiti na web stranici ili putem e-maila generalnog tajnika WoodEMA, i.a.

Sloboda oblikovanja vlastitog prostora – AMBIENTA 2012.

Od 10. do 14. listopada 2012. na Zagrebačkom je velesajmu održan 39. međunarodni sajam namještaja, unutarnjeg uređenja i prateće industrije – *Ambienta 2012.*, vodeći sajam u ovom dijelu Europe.

Premda se i ove godine osjeća kriza koja je neizbježno zahvatila i sektor proizvodnje namještaja i pratećih proizvoda, ipak se, za razliku od prošle godine, u smislu trendova i noviteta na ovogodišnjoj *Ambienti* osjećaju optimistični pomaci.

Sajam se prostirao na 38 000 m^2 izložbenog prostora u deset paviljona, uz sudjelovanje 341 izlagača iz 25 zemalja svijeta (Andore, Argentine, Austrije, Belgije, Bosne i Hercegovine, Brazila, Češke, Francuske, Hrvatske, Slovenije i dr.), koji su predstavili svoje najnovije proizvode, usluge i tehnologiju.

U deset sajamskih paviljona objedinjene su tri osnovne tematske cjeline: namještaj (namještaj za stanovanje, namještaj i oprema za kuhinje i kupaonice, uredski namještaj i namještaj za opremanje objekata), proizvodi i oprema za unutarnje i vanjsko uređenje te repromaterijali, strojevi i alati za drvnu industriju.

Na sajmu su se mogli vidjeti proizvodi tvrtki koje prate novitete na tržištu, predstavljaju se kvalitetom i originalnim dizajnom te nas ohrabruju u podizanju svijesti o kvaliteti stanovanja.

Zbog krize i štednje na *Ambienti* je ove godine izostao nastup velikih proizvođača poput virovitičkog Tvina, vinkovačke Spačve i čabarskog Finvesta. Njihov izostanak sajam je nastojao popuniti izlagačima iz BiH, koji su se nakon pet godina vratili na *Ambientu* s pet tvrtki i dizajnera.

Stoga takav iskorak i, najvažnije, *količina* dizajnerskih proizvoda s potpisom koji su se nakon dugo vremena ponovno pojavili na ovogodišnjem sajmu donosi veliku dozu optimizma. Pokazali smo da smo kreativni, a po inovativnosti i praćenju trendova zagrebački je sajam namještaja i prateće industrije *Ambienta* doista „Köln u malom“, prema riječima sveučilišnog profesora Ivice Grbca sa Šumarskog fakulteta i Studija dizajna u Zagrebu. Ako tome dodamo činjenicu da je ministar poljoprivrede Tihomir Jakovina s drvoprerađivačima potpisao ugovore u vrijednosti 60 milijuna kuna, optimizam je još veći.

Globalna kriza, koja je rezultirala i provođenjem manje vremena na poslu, utjecala je na to da ljudi ponovno otkrivaju toplinu vlastitog doma, u kojemu češće borave. Unutar svoja četiri zida imaju slobodu oblikovati vlastito okružje kako sami žele i osjećaju. Danas ljudi gledaju TV u kuhinji, kade integriraju u spavaće sobe, a stari se namještaj kombinira s novim. Individualnost i različitost važniji su nego ikada do sada, ali su i dalje u trendu bijela i svijetle pastelne boje te okruženost prirodnim materijalima – drvom, i to najčešće orahovinom.

U tom su smislu kampanja *Drvo je prvo* i Hrvatska gospodarska komora napravili važan korak okupivši hrvatske proizvođače u paviljonu 8.a, na više od 1600 m^2 povšine. Održan je poslovni klub s temom *Mogućnosti hrvatske drvne industrije na tržištu EU*, u organizaciji Ministarstva poljoprivrede, Udruženja drvnoprerađivačke industrije HGK, Šumarskog fakulteta i Zagrebačkog velesajma.

Zdrav san u posljednjih je nekoliko godina jedno od najvažnijih područja zanimanja. U tom smislu svakako treba istaknuti ovogodišnji hit na *Ambienti* koji je lansirala tvrtka *Bernarda*. Madrac *Thermo care* rezultat je novog pristupa zdravom spavanju zahvaljujući primjeni novih materijala pri izradi ležaja-madraca. *Bernarda* je za madrac *Thermo care*, dizajn Bernarda teama, dobila Zlatnu diplomu i plaketu *Mobil optimum 2012*, a isto su priznanje dobila i dva strana izlagača, Skyliving iz Njemačke i Rattan Sedia iz BiH.

Kuhinjski su izlošci na *Ambienti* potvrdili da proizvođači prate svjetske funkcionalne i vizualne trendove. Priznanje za kvalitetu i primjenu odgovarajućih materijala u izradi kuhinje *VISION* jest Srebrna plaketa i diploma *Mobil optimum 2012* koju je dobila tvrtka Sven d.o.o. iz Ludbrega, kao i Brončana plaketa i diploma *Mobil optimum 2012* što ju je dobila tvrtka Svea Lesna industrija d.d. iz Slovenije za visoku kvalitetu i oblikovanje kuhinjskog programa *GILIA*. Ista je nagrada pripala i tvrtki Sigma Plus iz Makarske, za oblikovanje namještaja za odlaganje *MOBILE*. Oblikovanje kuhinje podrazumijeva razveden i puni dijalog s prostorom, točnije dizajn cijelog okruženja, modulaciju punoga i praznog prostora kako bi se stvorio volumen. U kuhinji se živi kao u vanjskom svijetu, globalno i

Slika 1. Kuhinja *GILIA*, proizvođač Svea Lesna industrija d.d., Slovenija

Slika 2. Program WR 012, proizvođač Tehnohit iz Pitomače

Slika 3. Izložbeni prostor Zajednice za industrijski dizajn

Slika 4. Štand Šumarskog fakulteta Sveučilišta u Zagrebu

dinamično, u ravnoteži sa zdravim prirodnim ritmom i tehnologijom te istodobno fleksibilno, kreativno i otvoreno prema dnevnom boravku ili blagovaonici.

Kao i prethodnih godina, ojastučeni namještaj i dalje obilježavaju veliki formati. U tom smislu nema novosti (osim po količini). Ono što ovogodišnju *Ambientu* izdvaja od prethodnih godina jest znatno opsežnija prezentacija dizajnerskih uradaka i noviteta koji su nadmašili očekivanja. Među nezaobilaznim je izlagačima proizvođač ojastučenog namještaja Kvadra iz Svetog Križa Začretja, koji je imao najzapaženiji nastup i izložbeni prostor za koji je dobio posebno priznanje i Kristalnu skulpturu. Za inovativno oblikovanje oporabljenog drva u garnituri namještaja WR 012 tvrtka Tehnohit iz Pitomače dobila je Srebrnu plaketu i diplomu *Mobil optimum 2012,* kao i tvrtka Spin Valis iz Požege, koja je pokazala visoku kvalitetu i tradicionalnu primjenu cjelovitog drva u asortimanu proizvoda *AURORA*, koji je dizajnirala Sanja Horvat.

Namještaj od cjelovitog drva dobiva sve veće značenje, ponajprije zahvaljujući trendu zdravog življenja što se već nekoliko godina promovira u sklopu kampanje *Drvo je prvo*. U organizaciji Šumarskog fakulteta i Innova Wooda održano je 23. međunarodno savjetovanje pod nazivom *Drvo je prvo – znanjem i tehnologijom do konkurentnosti sektora šumarstva i prerade drva.* Nastup na sajmu brojni su dizajneri iskoristili za prezentiranje svojih radova, posebno Ada Studio, koji je izložio razvojni koncept proizvoda TriSq klupa Tq001 dizajnerice Ade Kezić, za koji je autorica dobila Brončanu plaketu i diplomu *Mobil optimum 2012.* Taj element u obliku slova „L" na vrlo se jednostavan način kombinira s drugim elementom u obliku slova „U", čime se postiže bezbroj varijanti različitih oblikovnih cjelina. Osnovna je građa cjelovito drvo, posebice slavonski hrast, bor, smreka i jela.

U sklopu *Ambiente* Agencija za strukovno obrazovanje i Zagrebački velesajam organizirali su stručni skup za nastavnike srednjih škola u obrazovnom podsektoru prerade i obrade drva, a ovogodišnja je tema bila dizajn namještaja. Zapažen nastup ove je godine imala i Zajednica za industrijski dizajn, koja djeluje unutar Centra za dizajn pri HGK.

Na *Ambienti* su se mogle vidjeti i brojne atrakcije poput lovačke kućice *Adut* iz Diviševca kod Slavonskog Broda, izložba postera u organizaciji Šumarskog fakulteta u Zagrebu, Burza ideja Studija dizajna, izložba završnih radova Odjela unutrašnje arhitekture Škole primijenjene umjetnosti i dizajna, izložba završnih radova studenata i nastavnika Šumarskog fakulteta, izložba Hrvatskih šuma, kao i mnogih drugih. Predavanja su održali dr. sc. Danijela Domljan, magistrica dizajna sa Šumarskog fakulteta, Igor Tomić, dipl. ing., predstavnik tvrtke Egger, a vlastita su dizajnerska i proizvođačka iskustva o dizajnu namještaja posjetiteljima prenijeli dizajneri Ada Kezić, arhitekt Kruno Kovač te direktor tvrtke Hrastico.

Kao zaključak se može istaknuti: ovogodišnja, 39. *Ambienta* nije nas razočarala.

Sigurno je da proizvođače i izlagače koji ove godine zbog globalne krize nisu imali dovoljno hrabrosti izložiti svoje proizvode očekujemo već sljedeće godine, kao i sve zainteresirane za novosti s područja drvne industrije

Ivan Žulj, dipl. ing.
Prof. dr. sc. Ivica Grbac

PYINKADO

NAZIVI

Drvo trgovačkog naziva pyinkado pripada botaničkoj vrsti *Xilia dolabriformis* Benth., iz botaničke porodice *Leguminosae*. Ostali su nazivi pyinkado (SAD, Velika Britanija, Francuska, Italija, SR Njemačka, Burma), ironwood (Velika Britanija), boja, jambe, kada, kongora, suria (Indija), mai deng (Tajland), cam-xe (Vijetnam), sokram (Kambodža), acle (Filipini), deng (Laos).

NALAZIŠTE

Vrsta drveta pyinkado uspijeva u južnoj i jugoistočnoj Aziji. Rasprostranjena je u Indiji, Burmi, Kambodži, Sjevernome i Južnom Vijetnamu te na Filipinima. Moguće ga je pronaći na području tropskih nizinskih trajnozelenih kišnih šuma, a često se pojavljuje zajedno s tikom (*Tectona grandis* L.).

STABLO

Stabla drveta pyinkado obično narastu do 35 metara visoko, a dužina čistog debla iznosi od 15 do 20 metara. Promjer deblovine je do 1,6 metara. Debla su cilindrična, pravilna. Kora im je siva do crvenkastosmeđa, nepravilno raspucana, nalik na koru platana. U sušnim područjima stabla su obično manja i manjih promjera te su često nepravilna rasta, a u šumama Burme narastu do većih visina i postignu veće promjere.

DRVO

Makroskopska obilježja

Drvo pyinkado difuzno je porozno i jedričavo. Godovi su teško uočljivi. Traheje su jedva vidljive golim okom, a drvni su traci uočljivi samo uz pomoć povećala. Bjeljika je uska, crvenkastobijela do svijetlo žutosmeđa. Srž je tamno crvenkastosmeđa do purpurnosmeđa. Drvo se opisuje kao tvrdo, teško do vrlo teško. Tekstura drva je umjereno do srednje fina, jednolična.

Mikroskopska obilježja

Traheje su pretežno raspoređene pojedinačno, u parovima ili u kratkim radijalnim nizovima, i malobrojne su. Na 1 mm^2 poprečnog presjeka može se naći 4 – 8 pora. Promjer traheja iznosi 70...125...180 mikrometara. Volumni je udio traheja u građi drva oko 18 %. Traheje u srži često su ispunjene tamnim sržnim tvarima. Aksijalni je parenhim paratrahealno vazicentričan, aliforman do konfluentan.

Volumni udio aksijalnog parenhima u građi drva iznosi oko 11 %. Drvni su traci jednoredni do dvoredni, homocelularni, difuzno raspoređeni. Stanice drvnih trakova često su ispunjene tamnim sadržajem. Drvni su traci visoki od 130 do 700 mikrometara, a širina im je od 11 do 45 mikrometara. Gustoća drvnih trakova je 8 – 14/mm. Volumni udio drvnih trakova u građi drva iznosi oko 14 %. Drvna su vlakanca libriformska, rijetko septirana. Duljina libriformskih vlakanaca je 1,15...1,49...1,93 milimetara, promjera 4,2...10,5...30 mikrometara, a debljina staničnih stijenki iznosi 1,5...3,5...6,0 mikrometara. Volumni je udio vlakanaca u građi goda oko 37 %.

Fizička svojstva

Gustoća standardno suhog drva, ρ_O	oko 870 kg/m^3
Gustoća prosušenog drva, ρ_{12-15}	910 do 1 250 kg/m^3,
Gustoća sirovog drva, ρ_s	prosječno 1 200 kg/m^3
Poroznost	oko 42 %
Radijalno utezanje, β_r	oko 3,3 %
Tangentno utezanje, β_t	oko 6,7 %
Volumno utezanje, β_v	od 10 do 12 %

Mehanička svojstva

Čvrstoća na tlak	71 ... 82... 89 MPa
Čvrstoća na vlak, okomito na vlakanca radijalno	3,4 MPa
tangentno	6,1 MPa
Čvrstoća na savijanje	130...145...160 MPa
Čvrstoća na smik radijalno	15 MPa
tangentno	16,5 MPa
Tvrdoća (prema Janki) paralelno s vlakancima	95 MPa
okomito na vlakanca	vrlo tvrdo
Modul elastičnosti	oko 17,8 GPa

TEHNOLOŠKA SVOJSTVA

Obradivost

Drvo se dobro obrađuje strojnim i ručnim alatima. Alati se brzo zatupljuju, stoga se preporučuje drvo ispiliti u sirovom stanju. Obrada alatima zahtijeva veći utrošak energije. Drvo se teško reže, ljušti i cijepa. Pri upotrebi vijaka i čavala drvo je potrebno prethodno izbušiti. Tijekom obrade drva bruševina nadražuje sluznicu. Lijepljenje drva je otežano zbog smolastih sržnih tvari u njemu. Površine je prije lijepljenja potrebno obraditi otapalima. Površinska je obrada otežana.

Sušenje

Drvo se teško i sporo suši te zahtijeva pažljivo kontrolirane uvjete sušenja kako se ne bi izvitoperilo ili raspucalo. Za najbolje rezultate stabla bi trebalo rušiti za vrijeme kišne sezone ili ubrzo nakon nje, te odmah započeti sušenje sirovog drva ili ga držati u vodi do početka sušenja. Ispiljeni materijal treba natkriti i zaštiti od brzog sušenja.

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Zbog smolastih tvari u drvu pyinkada srž mu je prirodno vrlo trajna i otporna na insekte, gljive uzročnice truleži i marinske štetnike. Otpornost na termite usporediva je s otpornošću tikovine (*Tectona grandis*).

Srž drva izrazito teško prima zaštitna sredstva, dok je bjeljika srednje permeabilna.

Uporaba

Drvo pyinkada ponajprije se upotrebljava za teške konstrukcije u mostogradnji i brodogradnji te za izradu drvenih gatova. Pyinkado je iza tikovine najcjenjenije drvo u Burmi. Osobito se često upotrebljava za proizvodnju željezničkih pragova, za izradu kojih je jedno od najboljih u svijetu. Iskorištava se i za izradu drvenih podova (parketa, drvenih pješačkih i industrijskih staza), a poznato je kao specijalno drvo za izradu ručki alata i drvenih dijelova strojeva.

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Napomena

Struktura i ostala svojstva drva irul (*X. Xylocarpa*) i pyinkado (*X. Dolabriformis*) vrlo su slična, pa je te dvije vrste drva izrazito teško razlikovati. Kora drva i ulje dobiveno iz sjemenki upotrebljavaju se u medicinske svrhe.

Literatura

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