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A Comparative Analysis of Consumer Attitudes on the Use of Wood Products in Slovenia and Croatia

Analiza uporabe drvnih proizvoda u Sloveniji i Hrvatskoj

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ABSTRACT • *In this paper, we compare consumer perceptions and attitudes in the wood products sectors in Slovenia and Croatia presenting them on the basis of a random sample of Slovenian and Croatian citizens between the age of 25 and 65. Data were collected using the computer assisted telephone interviewing method (CATI). The results suggest that, generally, there is a positive perception regarding the use of wood in both countries. The study results can potentially be a good basis for creating awareness-raising campaigns on the advantages of using wood in both countries.*

Key words: *consumers, public opinion, timber construction, furniture industry, market potential, Croatia, Slovenia*

SAŽETAK • *U ovom su radu uspoređene percepcije i stajališta potrošača u sektoru drvnih proizvoda Slovenije i Hrvatske, a prikazane su na temelju slučajnog uzorka slovenskih i hrvatskih državljana u dobi između 25 i 65 godina. Prikupljanje podataka provedeno je uz pomoć računala primjenom metode telefonskog intervjuiranja (CATI). Rezultati pokazuju da, općenito, postoji pozitivna percepcija o uporabi drva u obje zemlje. Rezultati istraživanja potencijalno mogu biti dobro polazište za kampanju podizanja svijesti o prednostima uporabe drva u Sloveniji i Hrvatskoj.*

Ključne riječi: *potrošači, javno mnijenje, drvo u graditeljstvu, industrija namještaja, tržišni potencijal, Hrvatska, Slovenija*

1 INTRODUCTION
1. UVOD

Slovenia and Croatia have similar forest sectors and both countries have experienced similar problems in the manufacturing, sale and use of wood products in recent years due to the global recession. This study compares consumer attitudes and preferences in both countries with regard to wood furniture demand, consumer habits and attitudes towards wooden buildings. Although Croatia and Slovenia are both considered developed countries, and are similar in many ways, there are socio-economic differences between the two countries (Table 1). For example, Croatia, with a population over twice

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Table 1 Demographic indicators for Croatia and Slovenia
Tablica 1. Demografski pokazatelji za Hrvatsku i Sloveniju

Indicator / *Pokazatelj*	**Croatia** *Hrvatska*	**Slovenia** *Slovenija*
Population (million) 2010	4.5	2.0
GDP (US$ billion) 2010	60	50
Debt/GDP (2009/2010)	55.0%	31.4%
GDP Change (2010/2009)	-1.4%	-6.2%
Unemployment Rate 2010/2010)	17.6%	9.4%
Poverty Rate (2008/2010)	17%	13%

Source / *izvor*: CIA Factbook

that of Slovenia, has higher national debt, unemplyment and poverty. However, Slovenia was impacted more severely by the current recession with a contraction in GDP of over four times that of Croatia.

Table 2 compares forest-related information for Slovenia and Croatia. While Croatia has twice the forest area available for supplying wood, the per capita forest land is almost identical with 63 and 62 hectares, respectively for Croatia and Slovenia. Forest land ownership patterns differ between the two countries with publicly owned forests accounting for 78 percent of the total in Croatia and only 23 percent in Slovenia. Beech is the primary species found in both countries while oak is ranked second in Croatia and spruce is second in Slovenia. In addition, in 2007 wood consumption per capita in Slovenia was above the EU average, while in Croatia wood consumption per capita was the lowest (Figure 1).

A review of the literature identified many critical issues related to the increased use of wood as an environmentally friendly and sustainable material (Jelačić *et al*, 2010; Motik *et al*, 2004; Petersen and Solberg, 2005; Tykkä, 2009; Zbašnik Senegačnik *et al*, 2011). These authors discuss wood processing ranging from traditional artisan carpentry to the use of wood as a construction material, as well as strategies for using wood, and environmental and economic impacts of use of wood products and alternative materials.

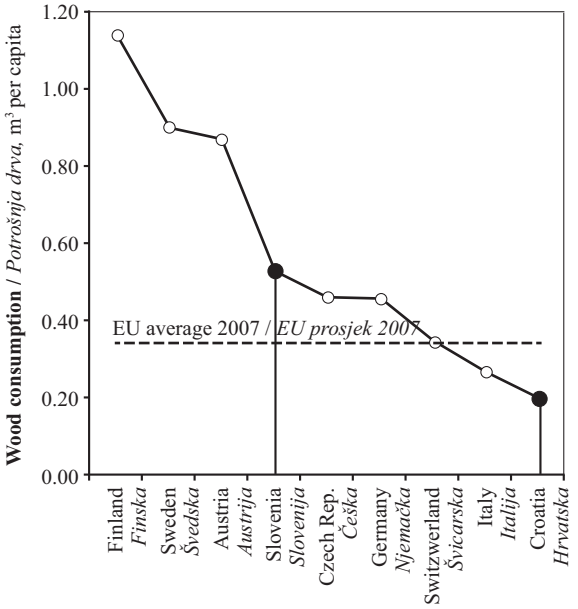

Figure 1 Consumption of sawn wood and wood based panels in selected countries per capita 2006, 2007, 2008 (Forest Products Statistics 2004–2008, 2009 – analyzed by M. Piškur, Surveying and Mapping Institute of Slovenia, 2011)
Slika 1. Potrošnja piljenog drva i drvenih ploča u odabranim državama po stanovniku 2006, 2007, 2008.

The primary objectives of this research were to: 1) describe domestic wood usage in the furniture manufacturing and in construction sectors of Croatia and Slovenia; 2) examine consumer perceptions of wood in each country and; 3) identify possibilities for increased consumer use of wood. We researched a number of topics including the determination of prefered construction methods, correlations between potential furniture use and perceptions of the timber industry. One of the main hypotheses was that there was no significant difference between the perception of a healthy living environment related to the use of wood; life-styles are

Table 2 A comparison of forests and other wooded land, growing stock and tree species in Croatia and Slovenia
Tablica 2. Usporedba šuma i drugih šumskih zemljišta, drvnih zaliha i vrsta drveća u Hrvatskoj i u Sloveniji

	Croatia / *Hrvatska*	**Slovenia** / *Slovenija*
Surface / *Površina* (1000 ha)	5,594	2,014
Forest and other wooded land *Šume i druga šumska zemljišta* (1000 ha)	2,689	1,274
Forest available for wood supply *Šume za opskrbu drvom* (1000 ha)	2,416	1,175
Forest and other wooded land *Šume i druga šumska zemljišta* (ha/capita)	0,63	0,62
Forest and other wooded land *Šume i druga šumska zemljišta* (percentage)	47%	63%
Publicly owned / *Javno vlasništvo* (1000 ha)	2,107	291
Private and other / *Privatno i drugo* (1000 ha)	582	962
Growing stock / *Drvna zaliha* (m^3/ha)	213	332
Increment / *Godišnji prirast* (m^3/ha)	3,9	7,8
Tree species / *Vrsta drveća* (percentage)	beech / *bukva* 36 %, oak / *hrast* 22 %, horbeam / *grab* 9 %, fir / *jela* 8 %, ash / *jasen* 3 %, spruce / *smreka* 2 %, other tree species / *druge vrste drveća* 20 %	beech / *bukva* 32 %, spruce / *smreka* 32 %, fir / *jela* 7.5 %, oak / *hrast* 7.4 %, pine / *bor* 5.9 %, valuable broadleaves / *vrijedne listače* 4.9 %, other tree species / *druge vrste drveća* 10 %

Source / *Izvor*: Eurostat Statistical Books, 2011, Hrvatske Šume d.o.o.

similar and the share of artisan furniture is fairly large both in Slovenia and Croatia.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

The sample frame for the study was structured according to population frequencies of the regional sectors in each country. Due to wide discrepancies of populations in study regions, the data were weighted by these population frequencies. 743 respondents were included in the study, 406 from Slovenian and 337 from Croatia. Data were collected conducted with the CATI method – computer assisted telephone interviewing (Kreuter *et al*, 2008). In Slovenia, the interview process took place from 15th December 2010 to 22nd December 2010; in Croatia, from 16th May to 27th May 2011. The survey questionnaire was developed by two research groups at the Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, and the Faculty of Forestry, University of Zagreb, in cooperation with the Chamber of Crafts and Small Business of Slovenia. Research group members had a broad expertise in the wood products sector including architecture, wood technology and construction.

The reliability of data depends on two factors: the size of the sample and the portion assessed. The smaller the share assessed, the larger the sample required; in the case samples of the same-size, assessments of smaller shares are less reliable. In this study, the degree of reliability for the population sample frame was tested at the 5 percent risk level with a resulting 95 percent probability that the sample population values are within the +/-5 percent confidence interval.

With regard to the questionnaire structure, respondents were presented with questions for 10 topical areas: 1) general perceptions of wood; 2) material selection when replacing windows in the respondent's home; 3) sources of information when selecting furniture; 5) preferences for domestic or foreign furniture manufacturers; 6) furniture replacement time frames; 7) the share of custom-made furniture in respondent homes; 8) desire to have more solid wood furniture in the home and reasons; 9) attitude towards a healthy living environment in connection with wood and; 10) home construction material preferences with regard to energy efficiency.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Respondent demographics
3.1. Demografska struktura uzorka

Table 3 summarizes demographic characteristics of respondents in each country. Generally, Slovenian respondents have a lower percentage of females, they are younger in age, less educated, and have higher personal incomes. Respondents from both countries have the same unemployment rate of 24 percent.

3.2 Perceptions of using wood
3.2. Percepcija uporabe drva

A bank of six statements were posed to respondents, which they rated on a Likert-type scale of 1–5, where 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree (Figure 2). On average, re-

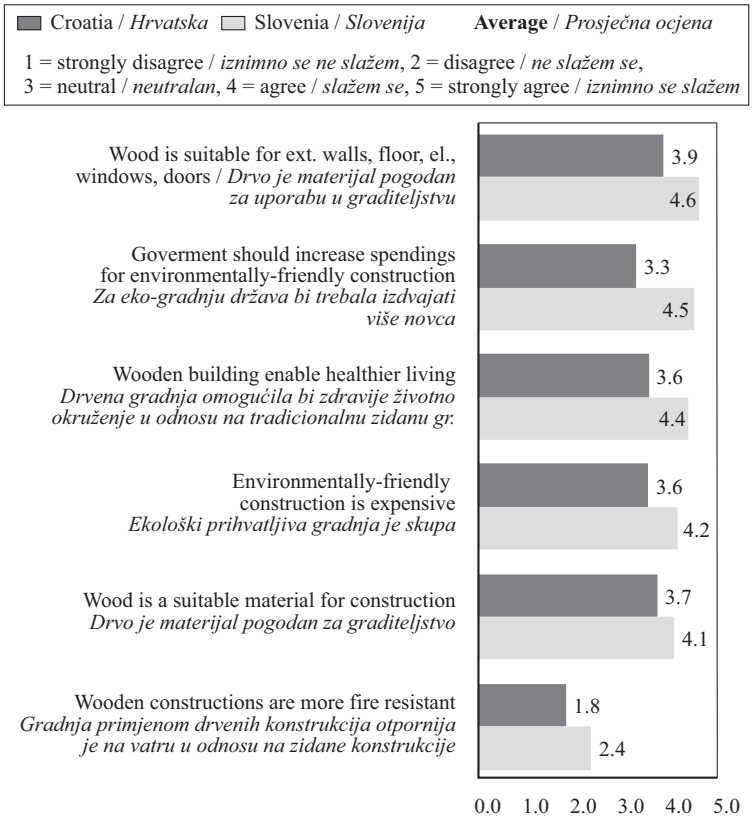

Figure 2 General perceptions about wood (Croatia, n=337; Slovenia, n=406)
Slika 2. Tvrdnje o gradnji drvom, ekologiji i zdravome životnom okruženju (Hrvatska, n=337; Slovenija, n=406)

Table 3 Respondent demographic structure
Tablica 3. Osnovne informacije o istraživanju i demografskoj strukturi uzorka

		Slovenia *Slovenija, %* n=406	**Croatia** *Hrvatska, %* n=337
Gender / *Spol*	Male / *muški*	47	55
	Female / *ženski*	53	45
Age / *Starost*	Years / *godina 25–30*	14	31
	Years / *godina 31–40*	27	24
	Years / *godina 41–50*	33	27
	Years / *godina 51–65*	26	18
Education *Obrazovanje*	Elementary school or less / *osnovna i niža škola*	9	2
	Vocational school / *strukovno obrazovanje*	21	20
	Secondary school / *četverogodišnja srednja škola*	32	39
	Graduate and postgraduate / *viša, visoka škola i više*	38	39
Personal income *Osobni dohodak*	Up to EUR 365 / *do 365 EUR*	12	27
	EUR 365–EUR 730	29	39
	EUR 730–EUR 1100	34	24
	EUR 1100–EUR 1460	16	8
	Above EUR 1460 / *iznad 1460 EUR*	9	2
Employment status *Zaposlenost*	Employed / *zaposlen*	76	76
	Unemployed / *nezaposlen*	24	24
Slovenian Regions *Slovenska regija*	Central Slovenia / *središnja Slovenija*	29	
	East Štajerska / *Istočna Štajerska (Maribor)*	18	
	Savinjska Region / *Savinjska regija (Celje)*	14	
	Gorenjska Region / *Gorenjska regija*	11	
	Dolenjska Region / *Dolenjska regija*	10	
	Prekmurje Region / *Prekomurska regija*	7	
	Goriška Region / *Goriška regija*	6	
	Littoral and Inner Slovenia / *Obalna i unutrašnja Slovenija*	5	
Croatian Regions *Hrvatska regija*	Zagreb County / *Zagrebačka županija*		7
	Krapina-Zagorje County / *Krapinsko-zagorska županija*		3
	Sisak-Moslavina County / *Sisačko-moslavačka županija*		5
	Karlovac County / *Karlovačka županija*		3
	Varaždin County / *Varaždinska županija*		5
	Koprivnica-Križevci County / *Koprivničko-križevačka županija*		2
	Bjelovar-Bilogora County / *Bjelovarsko-bilogorska županija*		3
	Primorje-Gorski Kotar County / *Primorsko-goranska županija*		7
	Lika-Senj County / *Ličko-senjska županija*		1
	Virovitica-Podravina County / *Virovitičko-podravska županija*		2
	Požega-Slavonija County / *Požeško-slavonska županija*		2
	Brod-Posavina County / *Brodsko-posavska županija*		4
	Zadar County / *Zadarska županija*		4
	Osijek-Baranja County / *Osječko-baranjska županija*		7
	Šibenik-Knin County / *Šibensko-kninska županija*		3
	Vukovar-Srijem County / *Vukovarsko-srijemska županija*		5
	Split-Dalmatia County / *Splitsko-dalmatinska županija*		11
	Istra County / *Istarska županija*		5
	Dubrovnik-Neretva County / *Dubrovačko-neretvanska županija*		3
	Međimurje County / *Međimurska županija*		3
	City of Zagreb / *Grad Zagreb*		15

spondents from Slovenia had significantly higher levels of agreement for all statements in this section. In addition, all responses were, on average, above the midpoint of 3.0 except for the statement "Wooden construction is more fire resistant than aslternative construction methods", which had average respondent values of 1.8 and 2.4 for Croatia and Slovenia, respectively. Generally, wood is viewed as a viable construction and value-added product material that promotes a healthy living environment. Respondents believe that environmentally friendly construction is expensive but that their respective governments should (co-finance) environmentally-friendly construction.

3.3 Material selection in replacing windows
3.3. Odabir materijala pri zamjeni prozora

Respondents were asked which materials they would use when replacing old or purchasing new windows. Multiple responses were possible. In addition,

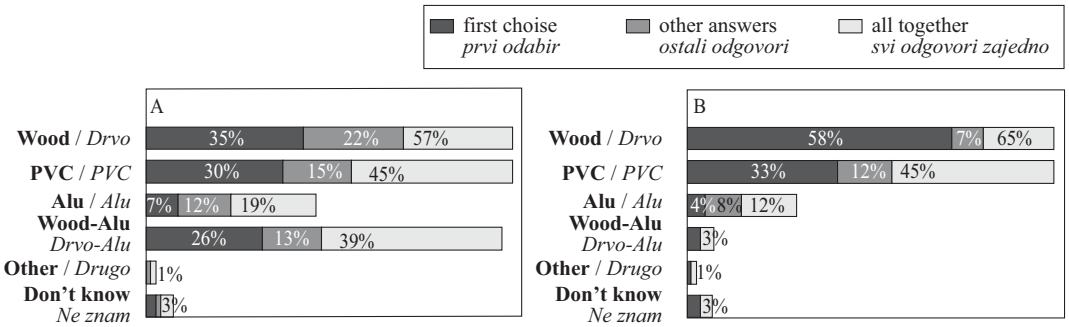

Figure 3 Answers to "If you decided to replace or purchase windows, which material would you choose?" Percentage of respondents. Multiple responses possible (A – Croatia, n=336, B – Slovenia, n=406)
Slika 3. Odgovori na pitanje"Kad biste se odlučili za zamjenu ili kupnju prozora, koji biste materijal izabrali?" (A – Hrvatska, n=336, B – Slovenija, n=406)

respondents indicated their "first choice" of material. We also show the total of "other answers" for each category, as well as grand total for "first choice plus" "other answers". Figure 3 shows that the largest share of respondents would choose wood (Slovenia: 58 percent; Croatia: 35 percent), followed by polyvinyl chloride (PVC), a thermoplastic polymer. Wood-aluminum is ranked third in Croatia, and aluminium in Slovenia. Other materials were selected by significantly fewer respondents. It should be noted that the grand total for "first choice plus" "other answers" for wood is 65 percent in Slovenia and 57 percent in Croatia.

3.4 Furniture selection criteria
3.4. Kriterij pri odabiru namještaja

Respondents were asked where they acquire information when selecting furniture (Figure 4). Multiple responses were possible. In addition, as is the case for product selection previously discussed, respondents indicated their "first choice" of material. The total of "other answers" for each category as well as grand total for "first choice plus" "other answers" are also shown. In Slovenia, shopping centers were ranked first by 25 percent of respondents and an additional 23 percent of respondents selected shopping centers as ranked lower than first choice; the combined share of respondents totaled 49 percent. Internet offers were ranked second and magazine information third. Online offers were ranked first in Croatia, followed by information found in shopping centers.

3.5 Domestic vs. foreign manufacturers
3.5. Domaći proizvođači nasuprot stranima

We were interested in whether respondents prefer domestic or foreign furniture manufacturers (Figure 5). Slovenian respondents were more opinionated with 72 percent preferring domestic manufacturers compared to 40 percent of Croatian respondents. Thirty-nine percent of Croatian respondents were undecided relative to 23 percent of Slovenian respondents.

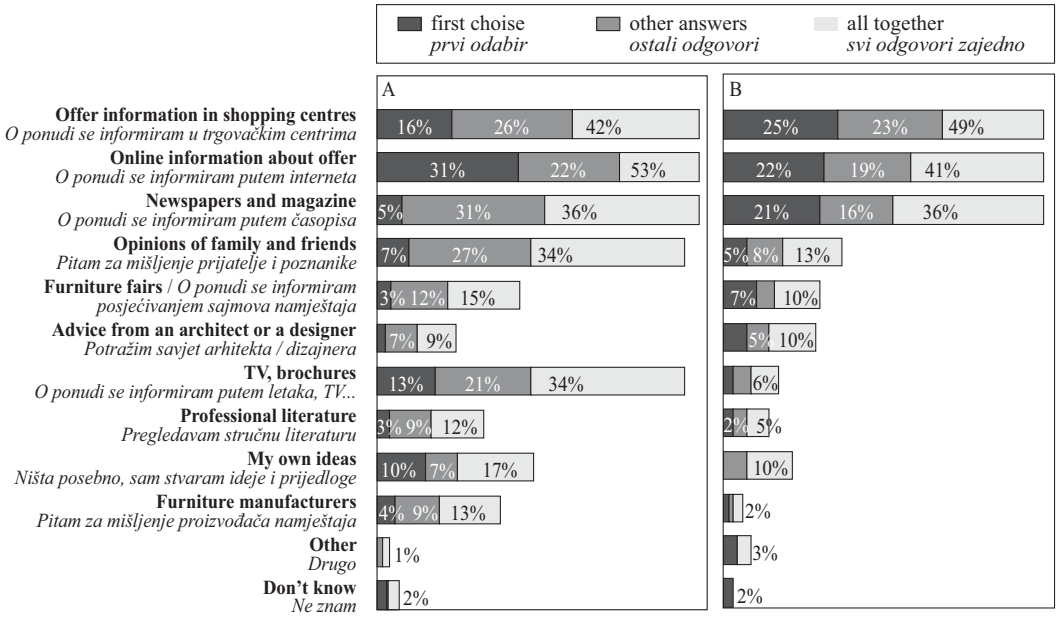

Figure 4 Answers to "Before purchasing furniture, where do you look for ideas / advice / information on furniture?" Percentage of Respondents (A – Croatia, n=336, B – Slovenia, n=406)
Slika 4. Odgovori na pitanje "Gdje prije kupnje tražite ideje / savjete / informacije o namještaju?" (A – Hrvatska, n=336, B – Slovenija, n=406)

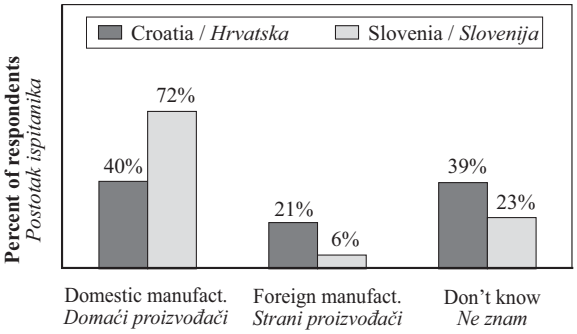

Figure 5 Answers to the question "When purchasing furniture, do you prefer domestic or foreign manufacturers?" (Croatia, n=337, Slovenia, n=406)
Slika 5. Odgovori na pitanje " Izabirete li pri kupnji namještaja radije domaće ili strane proizvođače?" (Hrvatska, n=337, Slovenija, n=406)

3.6 Furniture replacement
3.6. Zamjena namještaja

In the question that followed, we asked respondents when they planned to replace their living-room furniture (Figure 6). Twelve percent of Slovenian respondents plan to replace their living-room furniture by the end of 2011 relative to four percent of Croatians. For those respondents that plan to replace furniture, the highest percentage of respondents in Slovenia plan to do so in the 5-10 year period (20 percent) while 24 percent of Croatian respondents plan to do so in the 3-5 year period. Twenty-eight percent of Slovenian respondents and 12 percent of Croatian respondents have no plans to purchase new living-room furniture.

3.7 Custom-made vs. mass-produced furniture
3.7. Namještaj po mjeri nasuprot namještaju za masovnu uporabu

Respondents were then asked about the number of custom-made furniture and mass-produced pieces of furniture they currently have in their homes. The percentage of custom-made furniture was then calculated (Figure 7). On average, for both Slovenian and Croatian respondents, about 30 percent of furniture was custom-made. Two and six percent of Croatian and Slovenian respondents, respectively, own 100 percent custom-made furniture.

3.8 Desire to own more wooden furniture
3.8. Želja za posjedovanjem više drvenog namještaja

We were also interested in whether respondents would like to own more pieces of solid wood furniture and the reasons why (Figure 8). Respondents indicated their "first choice" of reason. The the total of "other answers" for each category as well as grand total for "first choice plus" "other answers" are also shown. In Slovenia, the percentage of respondents who would like to own more pieces of solid wood furniture and those who would not is 54 percent and 46 percent, respectively. However, in Croatia, the ratio is 64 percent and 36 percent. The primary reasons for desiring solid wood furniture are similar in Slovenia and Croatia: aesthetics, quality and durability, environmental-friendliness, health, warmth and homey appearance.

3.9 Wood and a healthy living environment
3.9. Drvo i zdrava životna okolina

After we stated to respondents that a healthy living environment is tied to the use of wood, purposely biasing responses, we asked the respondents if they were willing to spend more for a healthier living environment. Respondents indicated their "first choice" of room. The total of "other answers" for each category as well as grand total for "first choice plus" "other answers" are also shown. Only 10 percent of the respondents were not willing to spend more. Others (86 percent in Slovenia and 99 percent in Croatia) would invest primarily in living rooms, bedrooms and kitchens (Figure 9).

3.10 Home construction and energy efficiency
3.10. Izgradnja kuće i energetska učinkovitost

In Slovenia and Croatia, timber panel construction (prefabricated construction) has existed for over

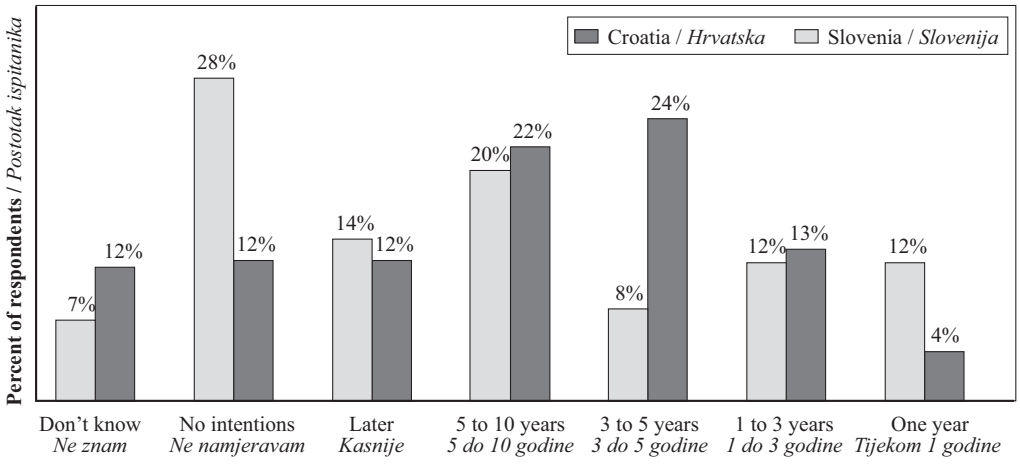

Figure 6 Answers to the question "When do you plan to replace your living-room furniture?
(Croatia, n=327, Slovenia, n=406)
Slika 6. Odgovori na pitanje "Kad namjeravate promijeniti namještaj u dnevnoj sobi?" (Hrvatska, n=327, Slovenija, n=406)

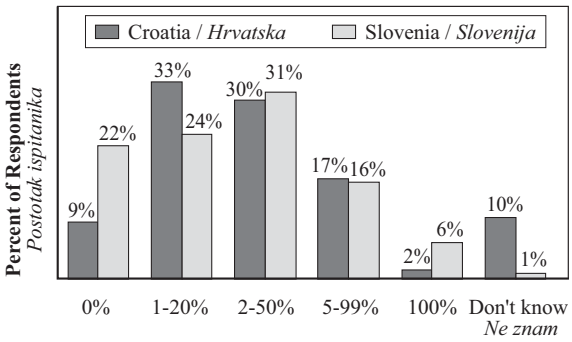

Figure 7 Answers to the question "What is the share of custom-made furniture in your home?" (Croatia, n =327, Slovenia, n =406)
Slika 7. Odgovori na pitanje "Koliki je u vašem stanu udio namještaja napravljenoga po narudžbi?" (Hrvatska, n=327, Slovenija, n =406)

35 years. We were therefore interested whether respondents would prefer low-energy construction or prefabricated timber construction if they hypothetically were to build a new house today. The results show that 51 percent of Slovenian respondents would choose traditional construction, 32 percent would choose prefabricated timber construction implemented by a recognized manufacturer of low-energy timber houses, and 10 percent would undertake the project themselves. In Croatia, traditional low-energy construction is ranked first with 51 percent of respondents, 18 percent would choose timber construction by recognized manufacturers, whereas 18 percent would undertake the project themselves. It is worthless that 30 percent of Croatian respondents were undecided (Figure 10).

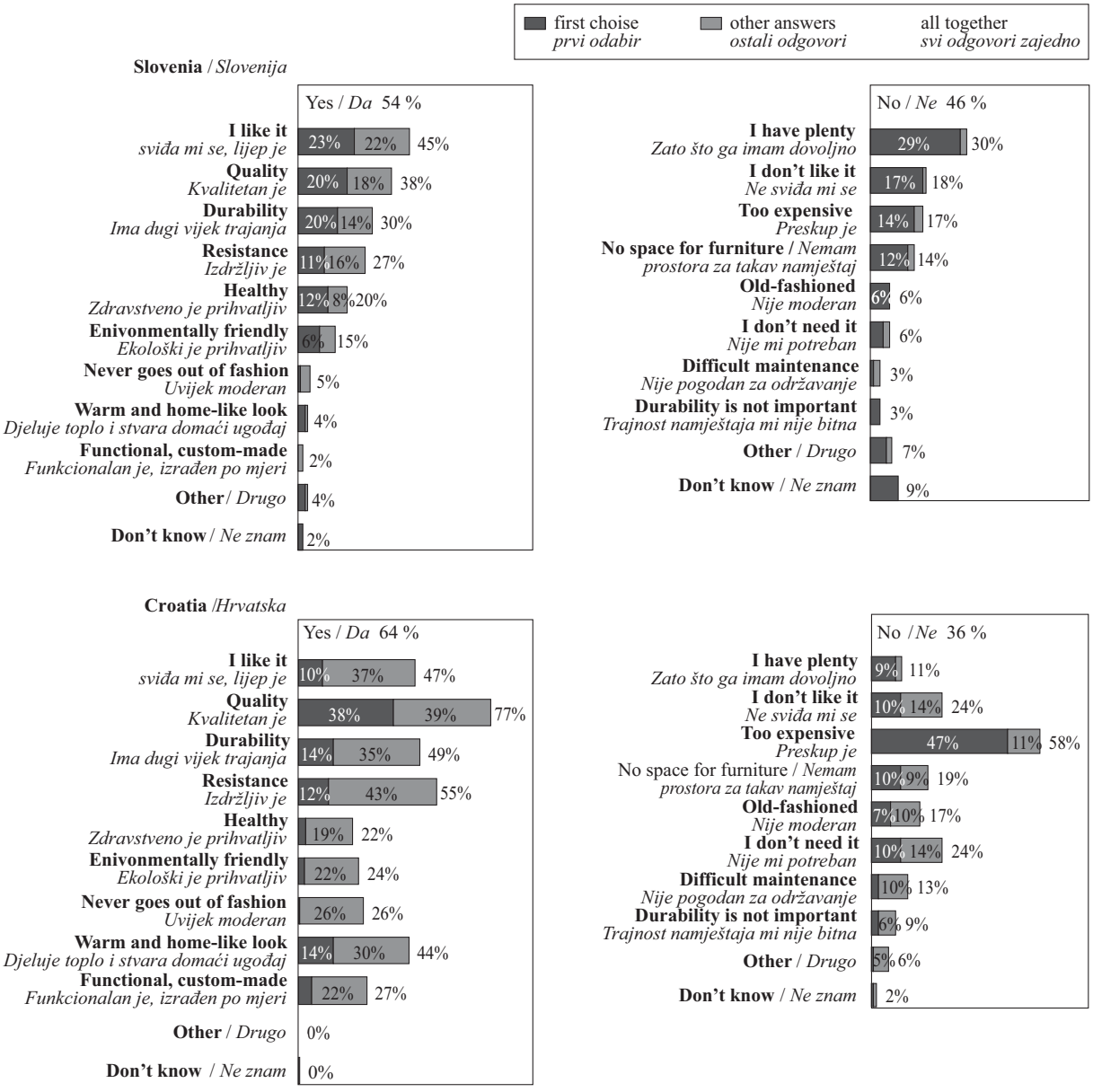

Figure 8 Answers to the question "Would you like to have more pieces of solid wood furniture in your home?" "If so, why?" Percentage of respondents. Multiple responses possible. (A – Croatia, n =329, B – Slovenia, n =406)
Slika 8. Odgovori na pitanje "Želite li u svom domu imati više masivnog namještaja?"
*(*A – Hrvatska, n =329, B – Slovenija, n =406)

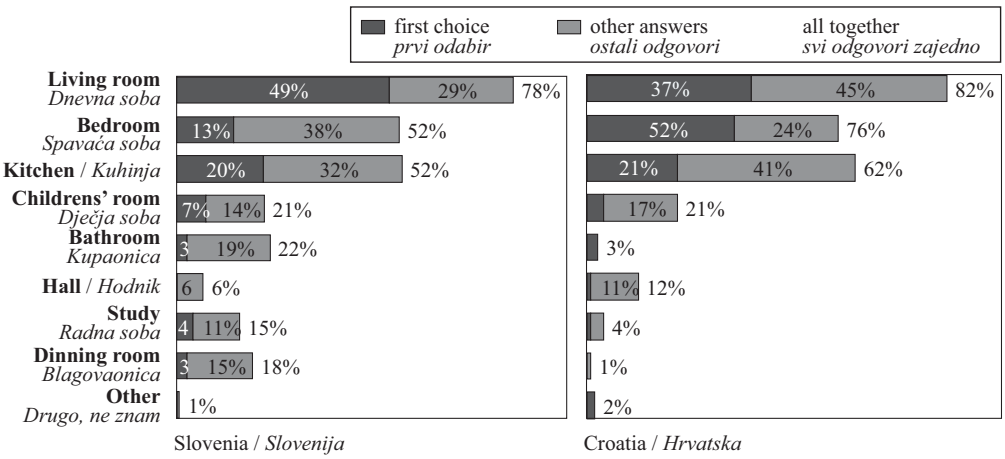

Figure 9 Answers to the question "Which living spaces would you invest in to ensure a healthy living environment?" Percentage of respondents. Multiple responses possible. (Croatia, n =330, Slovenia, n =350)
Slika 9. Odgovori na pitanje "Jeste li spremni platiti više da biste se pobrinuli za zdravu životnu okolinu? Za koje biste prostorije bili spremni platiti više?" (Hrvatska, n =330, Slovenija, n =350)

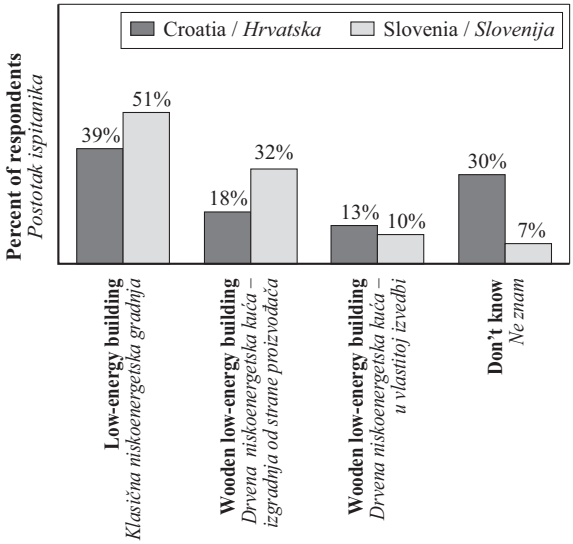

Figure 10 Answers to the question "If you decided to build a low-energy house, would you opt for traditional construction or a prefabricated timber house?" (Croatia, n =334, Slovenia, n =406)
Slika 10. Odgovori na pitanje: "Kad biste gradili novu niskoenergetsku kuću, kakvu biste gradnju izabrali? (Hrvatska, n =334, Slovenija, n =406)

4 CONCLUSION
4. ZAKLJUČAK

On the basis of the study and results obtained, the following can be concluded: both Slovenia and Croatia have a rich carpentry tradition, which is reflected in the answers of a relatively large share of respondents who own custom-made furniture. The results show that respondents in Slovenia and Croatia are willing to invest in a healthy living environment (made of wood), particularly in their living rooms.

The study results indicate that Croatian respondents believe that solid wood furniture is too expensive. The results show that more than a half of all respondents agreed that wood was an appropriate material for joinery and construction; they agreed to a much lesser extent that timber construction was fire resistant. They were also of the opinion that the government should allocate more funds (co-finance) environmentally-friendly construction. The results also show that more than 40 percent of Slovenian respondents would choose prefabricated timber construction, whereas in Croatia, a large share of respondents was undecided on which type of construction method they prefer, implying that they are not acquainted with the advantages of low-energy timber frame construction (Premrov, 2008), including: transition from on-site construction to prefabrication in a factory; transition from elementary measures to modular building; development from a single-panel to a macro-panel wall prefabricated panel system; and the speed of building. *The Slovenian Public Opinion Survey on Wooden Building* (Kitek Kuzman, 2009), conducted 5 years ago in Slovenia yielded results similar to those given by the Croatian respondents. It can therefore be suggested that Croatia will follow Slovenia's lead in using low-energy timber frame construction.

The results of this study can be useful to potential furniture retailers and distributors as well as importers of wood products as it is possible to establish the likely preferences of potential furniture buyers, as well as those who opt for timber construction. Generally, we provide an important overview of consumer preferences and use of wood in two Eastern European countries. Further research should replicate this study in other countries in order to gain a meaningful perspective on consumers in the region.

Acknowledgments – *Zahvala*

This study was a part of the Research Program "Wood and Lignocellulosic Materials" supported by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia. The authors want to thank this agency and the Chamber of Craft and Small Business of Slovenia.

5 REFERENCES
5. LITERATURA

1. CIA World Factbook. Various years. https://www.cia.gov/library/publications/the-world-factbook/
2. Eurostat Statistical books. 2011: Forestry in the EU and the world, A statistical portrait, pp.13-88.
3. Forest Products Statistics 2004-2008. 2009: Timber Bulletin, ECE / TIM / BULL / 62 / 2, analysed by M. Piškur, Surveying and Mapping Institute of Slovenia, 2011.
4. Jelačić, D.; Mat'ova, H.; Bičanić, K. 2010: Perception of Corporate Identity in Croatian and Slovakian Wood Processing and Furniture Manufacturing Companies. Drvna industrija, 61 (2):103-110.
5. Kitek Kuzman, M.; Medved S., Vratuša S. 2010: Evaluation of Slovenian contemporary timber construction. Drewno, 53 (183): 85-100.
6. Kitek Kuzman, M. 2009: Potential of Wooden Building in Slovenia. In: Kitek Kuzman (Ed.): Building with Timber, Challenge and Opportunity for Slovenia. University of Ljubljana, Biotechnical Faculty, Ljubljana, pp. 212-218.
7. Kreuter, F., Presser, S., Tourangeau, R. 2008: Social Desirability bias in CATI, IVR, and web surveys. Public Opinion Quarterly, 72 (5): 847-865 http://dx.doi.org/10.1093/poq/nfn063.
8. Motik, D.; Kusa, A.; Jazbec, A.; Jelačić, D. 2004: Comparision of furniture demand in Croatia and Slovakia. Forest Product Journal, 54 (12): 85-89.
9. Tykkä, S. et al. 2009, Development of timber framed firms in the construction sector — Is EU policy one source of their innovation? Forest Policy and Economics 12: 199-206.
10. Petersen, A. K.; Solberg, B. 2005: Environmental and economic impacts of substitution between wood products and alternative materials: a review of micro-level analyses from Norway and Sweden. Forest Policy and Economics 7: 249-259 http://dx.doi.org/10.1016/S1389-9341(03)00063-7.
11. Premrov, M. 2008: Timber frame houses. In: Handbook 1, TEMTIS project, (Educational materials of designing and testing of timber structures), Ostrava: VŠB-tu, Fakulteta stavební, pp. 1-15.
12. Zbašnik-Senegačnik, M.; Koprivec, L. , Kresal, J., 2011: Contemporary building skin: architecture-based survey of techniques and building technologies. Prostor (Zagreb), 19(1): 240-251.
13. ***www.hrsume.hr

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Šumarski fakultet Sveučilišta u Zagrebu

u suradnji s

organizira i poziva Vas na

23. MEĐUNARODNO ZNANSTVENO SAVJETOVANJE

"DRVO JE PRVO – ZNANJEM I TEHNOLOGIJOM DO KONKURENTNOSTI SEKTORA ŠUMARSTVA I PRERADE DRVA"

12. listopada 2012. godine, Zagrebački velesajam

Poštovani,

Naše tradicionalno savjetovanje u okviru 39. međunarodnog sajma namještaja, unutarnjeg uređenja i prateće industrije održat će se **12. listopada 2012.** na Zagrebačkom velesajmu. Tema ovogodišnjeg savjetovanja je "DRVO JE PRVO – znanjem i tehnologijom do konkurentnosti sektora šumarstva i prerade drva".

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doc. dr. sc. Goran Mihulja

Přemysl Veselý, Zdeněk Kopecký, Zdeněk Hejmal, Přemysl Pokorný[1]

Diagnostics of Circular Sawblade Vibration by Displacement Sensors

Dijagnostika vibracija lista kružne pile uz pomoć davača pomaka

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ABSTRACT • *The paper deals with problems of the circular sawblade vibration. In the introductory part, theoretical bases are summarized to determine the form of vibrations and critical and resonant rotational frequency. A diagnostic method is proposed for the direct measurement of amplitudes of a circular sawblade by displacement sensors with the subsequent Fast Fourier Transform (FFT) analysis. This method with the spectral analysis of a signal in the time area makes possible to determine the size and shape of vibration of a circular sawblade with respect to usability/applicability under operational conditions. Unlike standard methods, when the sawblade is excited by external sources, natural vibrations are used such as disk deformations and the dynamic unbalance of a circular sawblade, effects of chucking/gripping and machine vibration and, last but not least, the disk and sawn wood interaction.*

Keywords: *circular sawblade, critical rotational speed, resonant rotational speed, vibration, Fast Fourier Transform analysis*

SAŽETAK • *U radu se obrađuje problem vibracija lista kružne pile. U uvodnom dijelu daju se teorijske osnove za određivanje oblika vibracija te kritične i rezonantne frekvencije vrtnje. Predložena je dijagnostička metoda za neposredno mjerenje amplitude vibracija lista kružne pile uz pomoć davača pomaka i nakon toga uz pomoć Fast Fourierove (FFT) analize dobivenih podataka. Ta metoda sa spektarskom analizom realnog signala omogućuje određivanje veličine i oblika vibracija lista kružne pile uzimajući u obzir uporabljivost/primjenjivost metode u radnim uvjetima. Nasuprot standardnoj metodi, koja podrazumijeva pobudu lista pile na vibriranje vanjskim izvorima, u prezentiranoj se metodi iskorištavaju prirodni izvori pobude kao što su deformacija diska pile i dinamička neizbalansiranost, utjecaj vibracija stroja te interakcije lista kružne pile i obratka.*

Ključne riječi*: list kružne pile, kritična brzina vrtnje, rezonantna brzina vrtnje, vibracije, Fast Foruierova analiza*

1 INTRODUCTION
1. UVOD

Today circular sawblades for cutting wood-based materials are rather complicated tools equipped with various construction adjustments. The construction adjustments and arrangements are particularly aimed at eliminating the negative effects of circular sawblade vibrations on the quality of cutting but also at improving hygienic conditions in the workplace from the point of view of noise and dust. In the past, static and dynamic vibrations of the circular sawblade disk were subject to extensive research and described rather comprehensively. Vibrations and a zone where resonant

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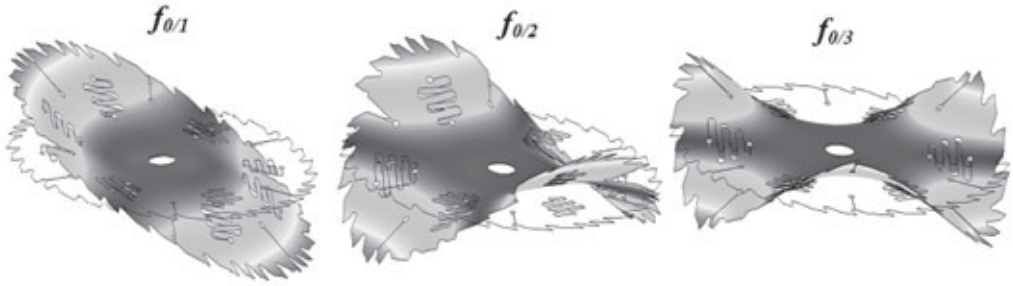


Figure 1 Central asymmetrical vibrations
Slika 1. Središnje asimetrične vibracije

and critical rotational frequency occur affect substantially the cutting parameters.

In consequence of its disk form, the circular sawblade can have an infinite number of eigenfrequencies, which are characterized by a certain form of vibrations. There are centrally symmetric vibrations with nodal circles $c = 0$ (f_0) and asymmetrical vibrations according to nodal diameters $k = 1, 2, 3$ to n ($f_{0/1}$, $f_{0/2}$, $f_{0/3, \ldots}$ $f_{0/n}$), see Fig. 1. In practice, the determination of the static frequency of the circular sawblade vibration is frequently dealt with experimentally. The creation of Chladni patterns is a diagnostic signal (Prokeš, 1978).

The form of vibrations and relevant eigenfrequencies of vibrations of a non-rotating disk can also be obtained by the Finite Element Method (FEM), (Kopecký *et al,* 2011), Fig. 1.

For the deflection w of the disk in point P on radius r and at the angle of turning φ a term (1) is given in literature (Nishio and Marui, 1996).

$$w = w(r,\varphi,t) = N(r,\varphi)\cdot \sin k\varphi \cdot \cos 2\pi \cdot f_{st} \cdot t \qquad (1)$$

where:
$w=w(r, \varphi, t)$ – circular sawblade disk deflection at vibrations expressed in a polar coordinate system (r, φ) in time t / *otklon lista pile pri vibriranju definiran u polarnom koordinatnom sustavu (r, φ) u vremenu t*, mm
w_O – deflection of point *O* / *otklon točke O*
$N(r,\varphi)$ – form function, which expresses the deflection of point *O* in a polar coordinate system / *funkcija oblika koja definira otklon točke O u polarnome koordinatnom sustavu*
f_{st} – frequency of eigenvibrations of a standing disk / *vlastita frekvencija mirujućeg lista pile*

If the disk rotates with frequency f_n, the following equation can be used for the angle of turning

$$\varphi = 2\cdot\pi\cdot f_n \cdot t \qquad (2)$$

By substitution into equation (1) and through an adaptation by means of the product of trigonometric functions $sin\alpha \cdot cos\beta$, the equation (1) can be transcribed into relation (3)

$$w(r,\varphi,t) = \frac{f(r)}{2}\cdot \sin 2\pi\cdot(f_{st} + k\cdot f_n)\cdot t - \frac{f(r)}{2}\cdot \sin 2\pi\cdot(f_{st} - k\cdot f_n)\cdot t \qquad (3)$$

The first element of the equation (3) represents a wave with the rotational speed of $60\cdot f_{st}/k$ (min^{-1}) progressing forwards, i.e. in the direction of rotation of the circular sawblade. The second element of the equation (3) represents a wave with the rotational speed of $60\cdot f_{st}/k$ (min^{-1}) progressing backwards, i.e. counter the rotation of the circular sawblade.

During research/development activities, an experimental method is often used (Siklienka and Svoreň, 1997). The determination of resonant and critical rotational frequency then results from the theory of vibration of a rotating circular sawblade. The dynamic frequency of vibration of a rotating circular sawblade f_d is quadratically affected by rotational frequency f_n (Stakhiev, 1989, 2003).

$$f_d = \sqrt{f_{st}^{\,2} + \lambda\cdot f_n^{\,2}} \qquad (4)$$

or

$$f_d = f_z + k\cdot f_n \qquad (5)$$

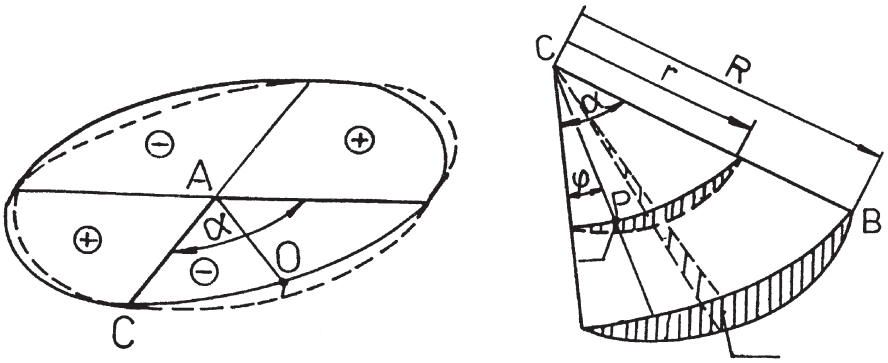


Figure 2 The sawblade disc deformation
Slika 2. Deformacije diska kružne pile

where:
f_{st} – eigenfrequency of vibrations of a non-rotating circular sawblade / *vlastita frekvencija mirujućeg lista pile,* Hz
k – number of nodal diameters (k = 1,2,3,4,5, ...) / *broj čvornih promjera*
f_z – frequency of backwards progressing wave / *frekvencija natrag putujećeg vala*
λ – coefficient of centrifugal force / *koeficijent centrifugalne sile*

An important output of the experiment consists in the coefficient of centrifugal force λ, which is subsequently calculated from relations (4) and (5) on the basis of measured frequencies f_{st}, f_z and the circular sawblade rotational frequency f_n. Then, by substitution into known relations (Siklienka and Svoreň, 1997), resonant (6) and critical (7) rotational frequency of a circular sawblade can be determined expressed in min^{-1}.

$$n_r = \frac{60 \cdot f_{st}}{\sqrt{(k+Z)^2 - \lambda}} \quad (6)$$

where:
Z – higher harmonic

$$n_k = \frac{60 \cdot f_{st}}{\sqrt{k^2 - \lambda}} \quad (7)$$

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

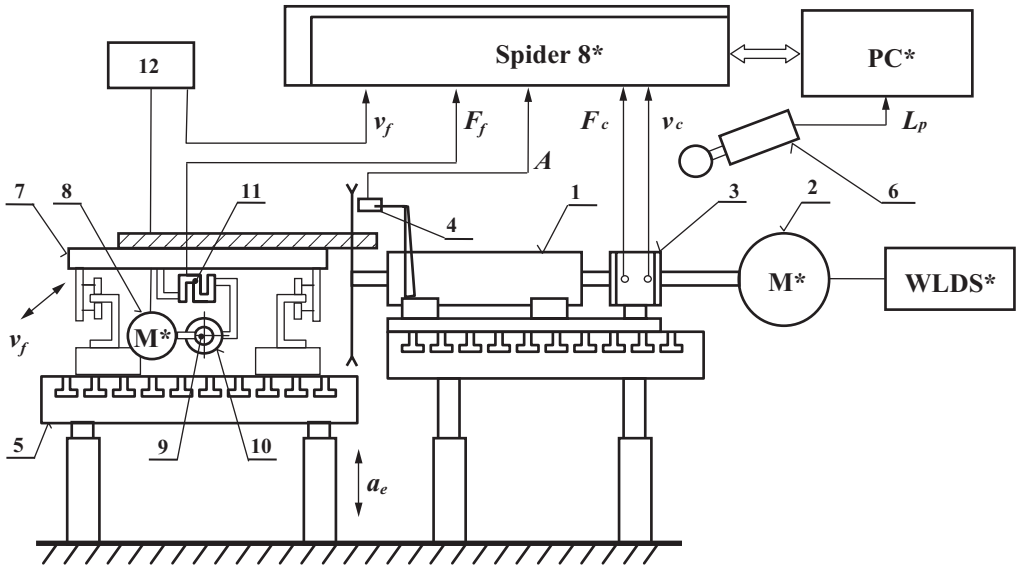
The subject of tests was a standard circular sawblade Pilana 400 x 4.4/3.2 x 30, 72 TFZL for large-area trimming to size. The proposed method consists in the position of sensors perpendicular to the circular sawblade area with a phase shift of 90°. Changing air gaps between sensors and the circular sawblade are recorded as the amplitude of vibration in two levels perpendicular to each other. The measurement was implemented on an experimental apparatus (see Fig. 3).

Unfortunately, the original setting of sensors with the phase shift of 180° did not bring definite results to determine the form of vibrations, particularly for the first and the second nodal diameter. At the present layout, which can be changed any time thanks to magnetic stands, sensors are placed at the sawblade rim at a level below teeth; teeth being shifted with one another by 90°.

Signals from sensors were transferred by a Spider 8 data logger to a PC and further processed using the Conmes Spider program. The course of vibration amplitudes on the disk rim was scanned with the sampling frequency of 300 Hz. Sampling frequency higher than 1200 Hz (weighted average-filtered frequency of 150 Hz) was used for reliable registration of unstable state. FFT analysis was done in program Skylab.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The aim of the newly designed method for measuring vibrations of the disk by displacement sensors is to obtain more detailed information on shapes of vibration without using rather complicated experimental stands. The possibility of diagnostics of a problematic circular sawblade directly on a saw under operational conditions is considered to be an advantage.



1 – spindle / *vreteno*, 2 – electric motor with adjustable speed (Ward Leonard Drive System) / *elektromotor s mogućnošću promjene vrtnje*, 3 – torque transducer with a speed sensor (HBM T34 FN) / *davač momenta sa senzorom brzine vrtnje*, 4 – contactless current displacement transducer (EPRO PR6423/000-001) / *beskontaktni davač pomaka*, 5 – grate table / *radni stol*, 6 – sound level meter / *zvukomjer*, 7 – feeding carriage / *posmični uređaj*, 8 – electric motor for the carriage feed / *elektromotor za posmak*, 9 – ball screw / *kuglični vijak*, 10 – nut / *matica*, 11 – feeding force sensor F_f / *senzor posmične snage*, 12 – frequency converter / *pretvarač frekvencije*

Figure 3 A scheme of the experimental stand
Slika 3. Shema provedbe eksperimenta

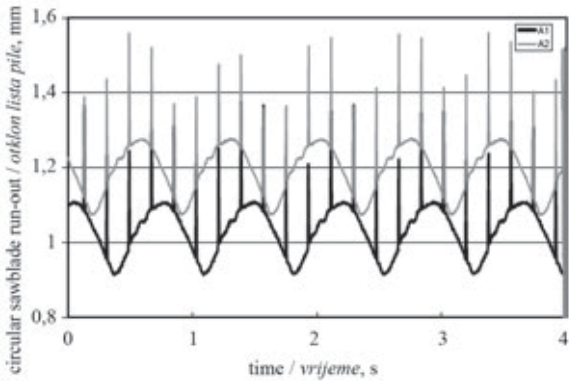


Figure 4 Running a circular sawblade at 83 min^{-1}
Slika 4. Vrtnja lista kružne pile frekvencijom 83 min^{-1}

The essential part of diagnostics of the disk vibration is the determination of the disk deformation and run-out. The results show whether the circular sawblade may be used for the process of cutting (in practice, max. allowable amplitude of run-out is 0.1 mm). At low rotational speed (83 min^{-1}), when the disk and spindle vibration are not affected by heat stress and tension as a consequence of centrifugal forces, both sensors (A1 and A2) measured max. amplitude of 0.08 mm, which can be considered to be a satisfactory value (see Fig. 4). The four radial compensatory grooves create the peaks.

When determening resonant and critical rotational frequency of a circular sawblade under operational conditions, it is first necessary to examine eigenfrequencies of vibration f_{st} of a standing circular sawblade f_n = 0. An impulse impact method (Orlowski *et al*, 2007) ranks among most suitable methods.

After a subsequent Fast Fourier Transform (FFT), it is possible to obtain natural frequencies of the sawblade disk vibration in particular nodal diameters (k = 1, 2, 3, …). If we compare eigenfrequencies of the tested disk obtained previously according to a conventional method using Chladni patterns (Kopecký, 2007), a very good consistency of analysed data can be noted. The eigenfrequencies of vibration were f_{st} = *89 Hz* for k=1, f_{st} =147 Hz for k =2 and f_{st} =261.9 Hz for k=3 (see Fig. 5).

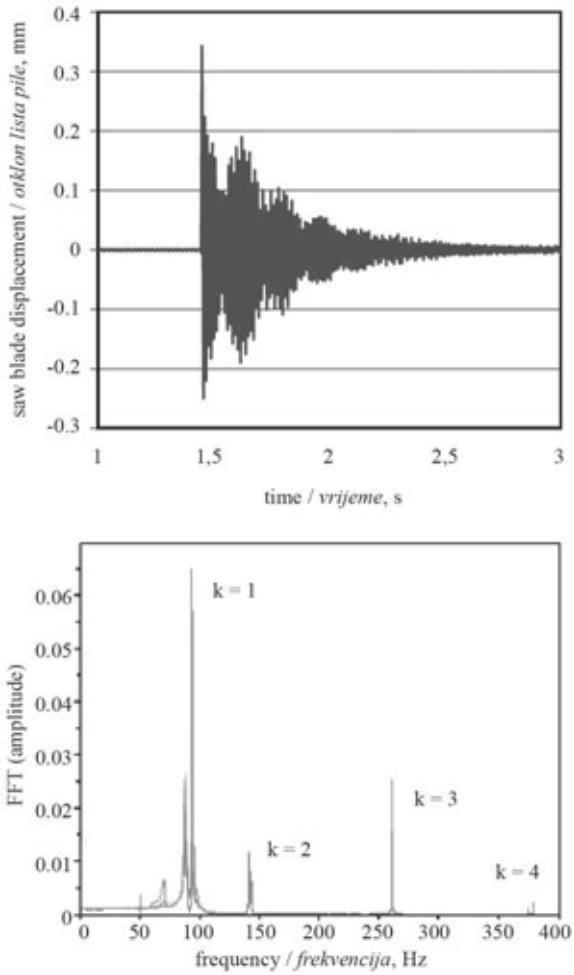


Figure 5 Impulse impact method and eigenfrequencies of the circular sawblade vibration by FFT
Slika 5. Metoda pobude lista pile i određivanje vlastitih frekvencija lista FFT analizom

With direct measurement of vibrations by displacement sensors, zones of increased vibrations and zones with low amplitude of vibrations were looked for in the next stage of the experiment (see Fig. 6). Based on the diagram, the applicable running speed ranging

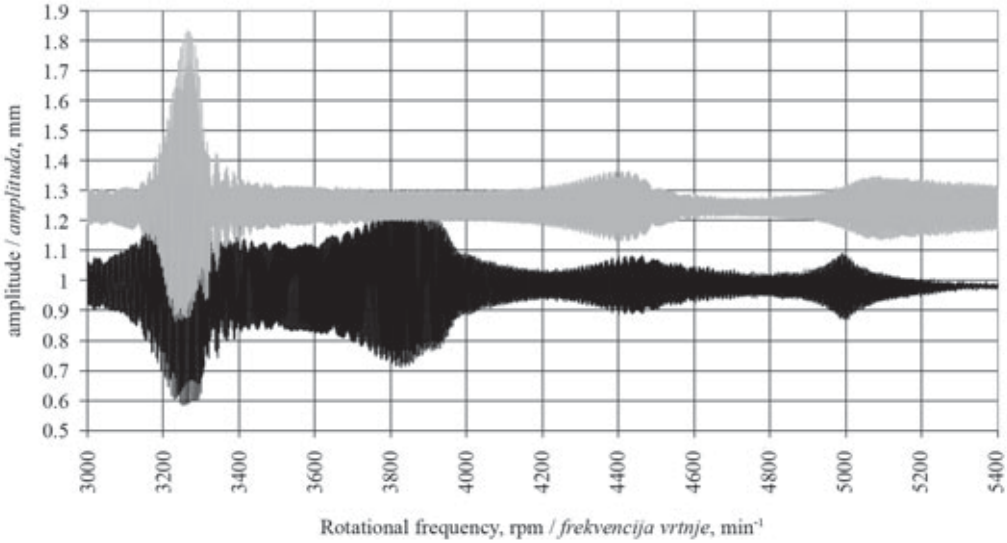


Figure 6 Changes of vibration amplitudes on the disk rim with the sensors A1, A2 shifted with one another by 90°
Slika 6. Promjene amplitude vibracija na rubu diska kružne pile određene davačima pomaka A1 i A2 pomaknutima za 90°

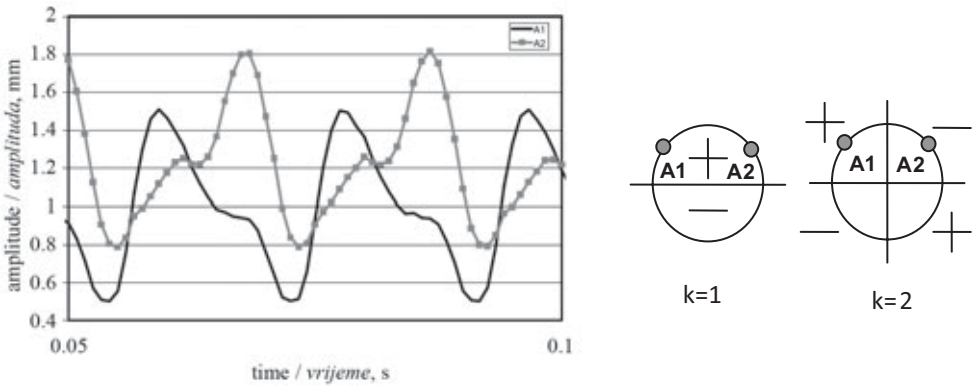


Figure 7 Record of vibration amplitudes at 3320 min^{-1} (55 Hz) sensed by sensors A1 and A2 with a phase shift of 90°
Slika 7. Amplitude vibracija lista pile pri frekvenciji vrtnje 3320 min^{-1} (55 Hz) zabilježene davačima pomaka A1 i A2 pomaknutima za 90°

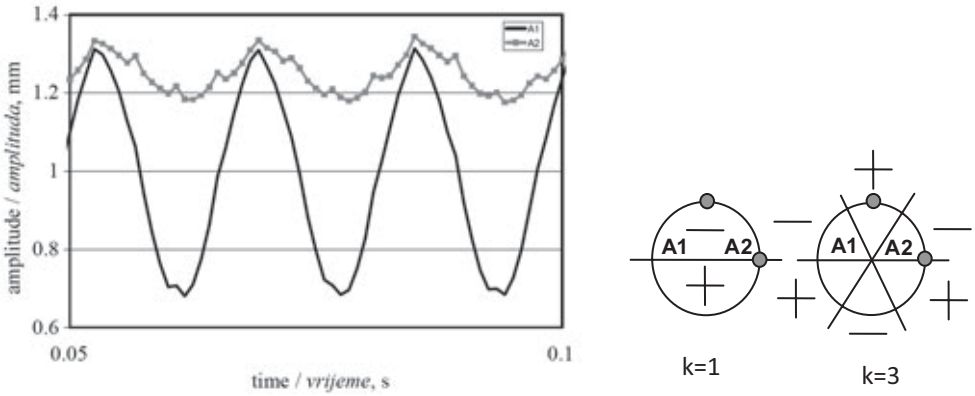


Figure 8 Record of vibration amplitudes at 3720 min^{-1} (62 Hz) sensed by sensors A1 and A2 with a phase shift of 90°
Slika 8. Amplitude vibracija lista pile pri frekvenciji vrtnje 3720 min^{-1} (62 Hz) zabilježene davačima pomaka A1 i A2 pomaknutima za 90°

between 4100 and 4200 min^{-1} can also be estimated without increasing vibration. Thus, it is evident that owing to the progressive wave motion, amplitudes of vibrations are roughly identical or several-fold different at certain rotational frequency.

It is known that at approaching the frequency of the disk vibration to the frequency of the disk rotation, unstable states occur. In unstable zones, more detailed measurements were carried out with the sampling frequency higher than 1200 Hz for reliable registration of the process. As an example, the records of vibration are given at 3320 and 3720 min^{-1} (see Fig. 7 and 8).

At 3320 min^{-1}, dominant vibrations of the first or the second nodal diameter can be expected. The curves of vibration amplitudes are approximately identical but turned up. The backward progressive wave is the cause of this effect (see Fig. 7).

At 3720 min^{-1}, dominant vibrations of the first or the third nodal diameter can be expected. The curves of vibration amplitudes are in phase. Sensor *A2* recorded small amplitudes, whose dimension failed to exceed the run-out. This point can be indicated as the balance point. Sensor *A1* recorded high amplitudes in accordance with max deflection (+ or -) of the disk.

FFT of a measured signal proved the hypothesis that at 3720 min^{-1} it referred to dominance of the first nodal diameter. After a more detailed analysis, the frequency of backwards progressive wave is evident at the first nodal diameter f_z = 49 Hz (see Fig. 9). In the amplitude-frequency spectrum, speed frequencies f_n = 62 Hz and its other harmonics also occur. FFT analysis was done from record of vibration amplitudes in program Skylab.

Based on the analysed data, rather good consistency is found of the determined frequency of a backward progressive wave with previous results obtained according to conventional methods (Kopecký, 2007), see Tab. 1.

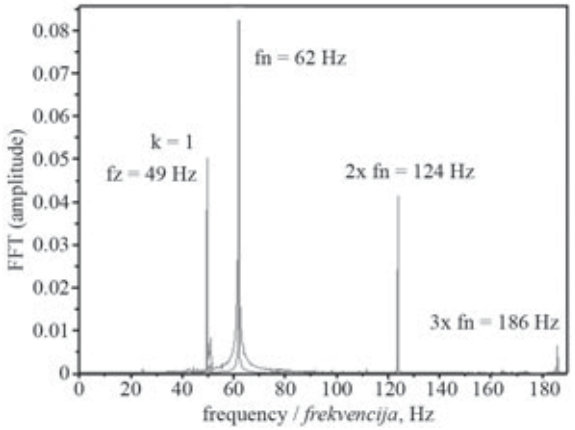


Figure 9 Amplitude-frequency spectrum of disk vibration at 3720 min^{-1} (62 Hz)
Slika 9. Spektar amplitude-frekvencija za vibracije lista pile pri frekvenciji vrtnje 3720 min^{-1} (62 Hz)

Table 1 Results of conventional method
Tablica 1. Rezultati konvencionalne metode

	Nodal diameter *k*=1 / *Čvorni promjer k=1*							
	Eigenfrequences of vibration f_{st} / *Vlastita frekvencija* f_{st}, Hz				89			
n, min^{-1}	2400	2600	2800	3000	3200	3400	3600	
f_z, Hz	61.8	59	57.8	57.4	55.6	54	50.2	
f_n, Hz	40	43.3333	46.6667	50	53.3333	56.6667	60	
f_d, Hz	101.8	102.333	104.467	107.4	108.933	110.667	110.2	$\phi\,\lambda$
λ	1.5264	1.35858	1.374008	1.445504	1.38708	1.347232	1.173067	1.373124

By substitution of the backward progressive wave f_z = 49 Hz into relation (5) the dynamic eigenfrequency of the rotating disk vibration f_d can be calculated and by a simple modification of the relation (4), the coefficient of centrifugal force λ for the given nodal diameter can be determined. The coefficient of centrifugal force is then an important parameter for the calculation of resonance or critical rotational frequency (see relations (6) and (7). In the analysed case, resonant frequency (Z = 1) of the first nodal diameter $n_{r1}(k1)$ is achieved at 3160 min^{-1}. A similar procedure can be applied for the second nodal diameter k=2 and the first critical rotational speed can be determined.

4 CONCLUSIONS
4. ZAKLJUČCI

The proposed method of the direct monitoring the circular sawblade vibrations by two displacement sensors provides more detailed information on unstable states of the circular sawblade, which are caused by natural processes at its rotation. Determination of the frequency of a backward progressive wave f_z with the possibility of an approximate determination of the coefficient of centrifugal force λ and calculation of resonance and critical rotational frequency is valuable information obtained from the amplitude-frequency analysis.

The method is, however, sensitive to the excitation of the disk vibration, e.g. from the disk dynamic unbalance, effects of fastening, changes in the inertia of drive and, last but not least, the machine vibration. An indisputable advantage consists in its application as the operational diagnostics of circular saws not requiring any disassembly. Thus, due to the easy mobility of sensors, it is possible to diagnose not only the particular circular sawblade but also a spindle, flanges or bearing clearance and to assess the effects of inaccuracies of these machine parts on the whole result of a cutting process.

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5 REFERENCES
5. LITERATURA

1. Kopecký, Z., 2007: Vybrané aspekty vysokorychlostního obrábění dřeva. MZLU Brno, (2007), 303 pp. [Habilitation thesis]
2. Kopecký, Z.; Veselý, P.; Rousek, M.; Karolczak, P., 2011: Wplyw konstrukcji pil tarczowych na poziom generowanego przez nie nateżenia dźwieku. In: Obróbka skrawaniem - Nauka a przemysl. No. 5. Politechnika Opolska: Wydawnictwo Sutoris Wroclaw, 2011. pp. 395-400.
3. Nishio, S.; Marui, E., 1996: Effects of Slots on the Lateral Vibration of Circular Saw Blade. Proccedings of the tenth Wood Machining Seminar, pp. 159-164.
4. Orlowski, K.; Sandak, J.; Tanaka, Ch., 2007: The critical rotational speed of circular saw: simple measurement method and its practical implementations. Journal of Wood Science 53: 388-393 http://dx.doi.org/10.1007/s10086-006-0873-5.
5. Prokeš, S., 1978: Obrábění dřeva a nových hmot ze dřeva. Praha, SNTL, 1978, 583 pp.
6. Siklienka, M.; Svoreň, J., 1997: Frekvencie vlastných tvarov kmitov pílových kotúčov při statickom kmitaní. TU Zvolen.
7. Stakhiev, Y. M., 1989: Rabotosposobnosť ploskich kruglych pil. Moskva: Lesnaja promyšlenost, 384 pp.
8. Stakhiev, Y. M., 2003: Research on circular saw disc problems: several of results. Holz als Roh- und Werkstoff 61: 13-22 http://dx.doi.org/10.1007/s00107-002-0353-6.

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Poboljšanje održavanja sustava navlaživanja u klasičnim komornim sušionicama

Improving of Maintenance of Humidifying System in Conventional Wood Kiln Dryers

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SAŽETAK • *Pri sušenju drva vrlo je čest problem taloženje vodenog kamenca na sastavne dijelove sušionica, posebno na sapnicama za raspršivanje vode, što je posljedica upotrebe „tvrde" i tehnološki nepripremljene vode. Često se upotrebljavaju neodgovarajuća sredstva za uklanjanje kamenca, koja štetno djeluju na opremu i ljude. Kako bi se smanjili materijalni troškovi nastali uporabom neodgovarajućih sredstava za uklanjanje kamenca i spriječilo potencijalno štetno djelovanje na zdravlje radnika, u ovom je radu istražena mogućnost primjene limunske kiseline u postupcima uklanjanja kamenca sa sapnica navlaživača klasičnih komornih sušionica. Tretirane su rabljene i nerabljene metalne sapnice navlaživača klasičnih komornih sušionica, pri čemu su primijenjene različite koncentracije vodene otopine limunske kiseline sobne temperature te provrela otopina (trajanje vrenja 5 i 10 minuta). Utvrđeno je da vodena otopina limunske kiseline sobne temperature ne daje pozitivne rezultate, dok čišćenje sapnica provrelom vodenom otopinom limunske kiseline već pri najmanjim koncentracijama daje iznimno dobre rezultate glede čišćenja kamenca i korozije, čime se postiže ponovna potpuna funkcionalnost sapnica. Nisu utvrđene negativne posljedice djelovanja limunske kiseline na tijelo metalnih sapnica.*

Ključne riječi*: klasična komorna sušionica, sušenje drva, sapnice navlaživača, vodeni kamenac, limunska kiselina monohidrat*

ABSTRACT • *During wood drying, the formation of limescale deposits on conventional drying kiln components frequently causes difficulties, especially on nozzles for dispersion of water mist, as a result of the use of "hard water" and technologically unprepared water. Frequently inadequate cleaners for the removal of limescale are used, which have harmful effects on the equipment and people. In order to reduce costs incurred due to the use of inadequate cleaners for the removal of limescale and to eliminate potentially harmful effects on the health of employees, the use of citric acid has been researched in procedures of removal of limescale from the moisturizer nozzles of the conventional drying kilns. Used and unused metal moisturizer nozzles of the conventional drying kilns have been treated with different concentrations of water solution of citric acid at ambient temperature and in boiled state for 5 and 10 minutes. It has been determined that the water solution of citric acid at ambient temperature does not give positive results, while the treatment of nozzles in the boiled water solution of citric acid gives very good results already at minimum concentration of citric acid, both for the cleaning of limescale and for the cleaning of corrosion, resulting in fully renewed functionality of nozzles. No adverse effects of citric acid on the body of metal nozzles have been recorded.*

Key words*: conventional wood drying kiln, wood drying, moisturizer nozzles, limescale, citric acid monohydrate*

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1. UVOD
1 INTRODUCTION

Kako se ljudi od prapovijesti koriste drvom, postoji i potreba za sušenjem drva iako se postupak koji mi danas poznajemo kao klasično komorno sušenje pojavljuje tek potkraj 19. stoljeća u Europi. Prije toga se drvo sušilo samo prirodnim putem. Potkraj 19. stoljeća francuske i pruske željeznice razvijaju sušionice za drvo u kojima drvo za vrijeme sušenja ne dolazi u dodir s dimnim plinovima, a tek od 1920. godine sušionice nalaze široku primjenu u drvnoj industriji i sve se više usavršavaju (Krpan, 1965). Klasično komorno (evaporacijsko) sušenje najzastupljeniji je i najistraživaniji oblik umjetnog sušenja drva u svijetu, i to zbog svoje ekonomičnosti, cijene, jednostavnosti uporabe i vođenja procesa sušenja te mogućnosti da se drvo prilično brzo osuši do najnižih sadržaja vode u drvu.

Bitan dio opreme u klasičnoj komornoj sušionici jesu navlaživači zraka. Kako se u praksi primjenjuju dva načina navlaživanja zraka unutar klasične komorne sušionice – raspršenom vodenom maglom i zasićenom vodenom parom, uvjeti unutar sušionice u kojima se drvo suši mješavina su zraka i vodene pare temperature do 100 ºC (Pervan, 2000). Zbog navlaživanja vodom u takvim se mikroklimatskim uvjetima vodeni kamenac (uglavnom karbonatne soli kalcija) iz vode taloži na sapnicama navlaživača. Naslage kamenca iz prirodnih voda često uzrokuju brojne tehničke i ekonomske probleme u industrijskim postrojenjima i kućnoj opremi time što uzrokuju otežan protok vode u cijevima i sapnicama ili ograničavaju prijenos topline u izmjenjivačima topline (Legrand i Leroy, 1990). Naslage kamenca nastaju i na membranama sustava reverzne osmoze, a najčešće se sastoje od kalcijeva karbonata i kalcijeva sulfata (Baker i dr., 1997). Činitelji koji obično utječu na nastanak naslaga kalcijeva karbonata jesu razina prezasićenosti, pH, temperatura i brzina toka vode (MacAdam i Parsons, 2004). Pri zagrijavanju vode najlakše se taloži kalcijev karbonat, koji se izlučuje toplinskim raspadanjem kalcijeva bikarbonata zbog otplinjavanja slobodne pripadne ugljične kiseline, pa su stoga procesi raspadanja kalcijeva bikarbonata i taloženje kalcijeva karbonata upola sporiji u zatvorenim vodnim sustavima i uglavnom su prouzročeni trošenjem ugljične kiseline na korozijske procese. Proces taloženja počinje već pri temperaturi od 20 do 30 °C, a intenzivira se s povišenjem temperature, tako da je na 100 °C raspadanje gotovo potpuno (Šivak, 2002). Najčešći uzrok taloženja kamenca na sapnicama navlaživača jest to što se u drvnoindustrijskoj praksi za navlaživanje često upotrebljava tvrda i tehnološki nepripremljena voda, što s vremenom trajanja procesa sušenja drva dovodi do potpunoga ili djelomičnog začepljenja sapnica navlaživača. To uzrokuje teškoće u održavanju zadanih parametara sušenja te je moguć nastanak grešaka sušenja. Topljivost soli tvrdoće u vodi smanjuje se zagrijavanjem te se one talože kao tvrdi talog, a kako su u sušionicama temperature zraka do 100 °C, vodeni se kamenac taloži na sapnicama zbog izloženosti višim temperaturama i mogućnosti lakšeg otplinjavanja slobodne pripadne ugljične kiseline. Taloženjem kamenca smanjuje se uporabna funkcija sapnica, te one više ne stvaraju finu raspršenu vodenu maglu nego zbog začepljenja polijevaju građu mlazom vode ili se sapnice potpuno začepe, što osim utjecaja na kvalitetu vođenja procesa sušenja i postizanja željenih parametara vlage unutar sušionice, dovodi i do pada kvalitete osušenog drva.

Prema provedenom istraživanju ukupne tvrdoće (tabl. 2), vode u Republici Hrvatskoj općenito se mogu kategorizirati kao srednje tvrde do tvrde (tabl. 1), pri čemu je problem tvrdoće izraženiji u primorskoj Hrvatskoj, osobito na otocima (Dadić, 2001). Na temelju tih spoznaja bez adekvatne tehnološke pripreme vode u drvnoj će se industriji pojavljivati problem taloženja vodenog kamenca na sapnicama navlaživača.

U praksi se čišćenje sapnica često provodi klorovodičnom kiselinom, tzv. solnom kiselinom (HCl) ili drugim neodgovarajućim sredstvima. Problem čišćenja klorovodičnom kiselinom jest njezina jačina i korozivna svojstva – ona nagriza metalnu površinu sapnica. Nakon nekoliko čišćenja klorovodičnom kiselinom sapnice gube svoje nazivne dimenzije i postaju neupotrebljive. Cijena metalnih sapnica prilično je visoka, stoga čišćenje klorovodičnom kiselinom uzrokuje nepotrebne troškove u sušioničkoj praksi. Osim toga, plastične se sapnice ne mogu čistiti klorovodičnom kiselinom. Klorovodična je kiselina također opasna za rukovanje, što od radnika u sušionicama zahtijeva poznavanje sigurnog načina rada s opasnim tekućinama, jer one djeluju nagrizajuće, uz opasnost oštećivanja dišnih organa, očiju, crijeva i kože. Najmanji stupanj zaštite tijekom rukovanja klorovodičnom kiselinom trebala bi biti uporaba zaštitnih gumenih ili PVC rukavica te nošenje zaštitnih naočala, a bilo bi poželjno nositi i kemijski otpornu odjeću i obuću. Opasnost od klorovodične kiseline ovisi i o njezinoj koncentraciji, a opasna je i u dodiru s određenim materijalima te pri miješanju s vodom, pri čemu može izazvati burne reakcije. Članak 17. Zakona o zaštiti na radu (NN 59/96, 94/96, 114/03, 100/04, 86/08, 116/08 i 75/09) obvezuje poslodavca na primjenu pravila zaštite na radu na temelju općih načela zaštite, i to na zamjenu opasnoga

Tablica 1. Klasifikacija prirodnih voda s obzirom na ukupnu tvrdoću (izvor: Šivak, 2002)
Table 1 Classification of natural waters with respect to total hardness (source: Šivak, 2002)

Klasa vode *Water class*	**Ukupna tvrdoća** *Total hardness*		
	°nj	mol/m^3	mg $CaCo_3$/L
Vrlo mekane *Very soft*	0-4	0-0,72	0-71,40
Mekane / *Soft*	4-8	0,72-1,43	71,40-142,80
Srednje tvrde *Moderate hard*	8-12	1,43-2,15	142,80-214,20
Prilično tvrde *Quite hard*	12-18	2,15-3,22	214,20-321,30
Tvrde / *Hard*	18-30	3,22-5,35	321,30-535,50
Vrlo tvrde *Very hard*	> 30	> 5,35	> 535,50

Tablica 2. Ukupna tvrdoća vode u nekim naseljima u Republici Hrvatskoj (izvor: Dadić, 2001)
Table 2 Total water hardness in some locations in the Republic of Croatia (source: Dadić, 2001)

Red. br. *Ordinal*	**Naselje** *Location*	**Ukupna tvrdoća** *Total hardness*	
		°nj	mg $CaCo_3$/L
1	Bjelovar	13,8	246,0
2	Čabar	14,4	257,0
3	Čakovec	14,7	262,0
4	Daruvar	3,1	56,0
5	Delnice	10,7	191,0
6	Dubrovnik	12	215,0
7	Dugo Selo	22,1	396,0
8	Gospić	12,7	228,0
9	Ivanec	13,0	232,0
10	Ivanić Grad	15,9	283,0
11	Karlovac	13,6	242,0
12	Koprivnica	15,2	271,0
13	Krapina	16,7	299,0
14	Križevci	13,4	240,0
15	Ludbreg	18,9	338,0
16	Novigrad (Istra)	19,1	340,0
17	Novska	21,7	388,0
18	Ogulin	11,0	196,0
19	Osijek	16,5	294,6
20	Otok Biševo	61,0	1086,0
21	Otok Lastovo	52,0	940,0
22	Otok Mali Drvenik	104,0	1864,0
23	Otok Murter	35,0	625,0
24	Otok Premuda	82,9	1480,0
25	Petrinja	10,2	183,0
26	Rijeka	7,0	125,5
27	Sisak	11,5	205,0
28	Slavonski Brod	21,0	375,0
29	Varaždin	22,0	392,0
30	Velika Gorica	22,7	406,0
31	Vinkovci	13,8	246,0
32	Virovitica	17,8	317,0
33	Vukovar	14,9	266,0
34	Zagreb - Centar	20,5	366,0
35	Zagreb - Črnomerec	20,5	366,0
36	Zagreb - Dubrava	22,1	394,0
37	Zagreb - Sesvete	23,0	410,0
38	Zaprešić	23,0	410,0

neopasnim ili manje opasnim sredstvom. Jedno od mogućih zamjenskih sredstava za čišćenje metalnih sapnica jest limunska kiselina, koja je slaba organska kiselina, prirodni je konzervans, a upotrebljava se u prehrambenoj industriji kao aditiv, u farmaceutskoj industriji, kao i za omekšavanje vode. Limunska je kiselina aktivni sastojak nekih sredstava za čišćenje kupaonica i kuhinja. Otopinom limunske kiseline koncentracije 6 % bez ribanja se mogu otkloniti mrlje tvrde vode na staklu, a u metalnoj se industriji upotrebljava za otapanje hrđe s čelika. Ujedno se primjenjuje i kao ekološki neškodljivo sredstvo za čišćenje. Na sobnoj je temperaturi u obliku bijeloga kristalnog praha. Limunska je kiselina slaba kiselina, ali ipak pri rukovanju njome treba biti oprezan te je potrebno nositi zaštitne naočale i rukavice. Naime, izloženost većim koncentracijama kiseline može dovesti do iritacije očiju i kože (tabl. 3). Zbog navedenih pozitivnih obilježja limunske kiseline cilj ovoga rada bio je pokus čišćenja metalnih sapnica vodenom otopinom limunske kiseline različitih koncentracija i temperature.

2. MATERIJALI I METODE
2 MATERIALS AND METHODS

Materijal za istraživanja bile su standardne sušioničke metalne sapnice od nehrđajućeg čelika aksijalnog usmjerenja mlaza na kojima su postojale nakupine kamenca što su uzrokovale slabo raspršivanje vode u zrak u sušionici. Uzorci koji više nisu zadovoljavali uvjete praktične primjene prikupljani su tijekom duljega vremenskog razdoblja u industrijskom pogonu. Sapnice predviđene za tretiranje podijeljene su u dvije skupine: 1. sapnice koje ne zadovoljavaju uvjete uporabe, a imaju samo naslage kamenca (u tablicama označene kao: **kam**), 2. sapnice koje ne zadovoljavaju uvjete uporabe i na sebi imaju naslage kamenca, ali su usto tijekom duljeg vremena stajanja korodirale (u tablicama označene kao: **kor**). Istraživanje je provedeno pri sobnim uvjetima: t_s = 20 ºC, φ = 58 %. Koncentracija limunske kiseline u destiliranoj vodi određena je preko masenih omjera uz pomoć staklene menzure i umjerene vage KERN 440-33N, s točnošću mjerenja d = 0,01 g i maksimalne mjerene mase m = 200 g. Istraživanje (čišćenje sapnica) provedeno je u vodenoj otopini limunske kiseline različitih koncentracija i tijekom različitih vremena tretiranja. Za ispitivanje učinka iste koncentracije vodene otopine limunske kiseline sapnice su tretirane u vodenoj otopini sobne temperature i u provreloj vodenoj otopini, tj. sapnice su prokuhavane.

Određeno je osam različitih postupaka tretiranja. Pri čišćenju uzoraka prokuhavanjem najprije je prokljućala otopina, a tek su tada u nju stavljani uzorci koji su prokuhavani određeno vrijeme, prema utvrđenom rasporedu. Za svako tretiranje uzete su dvije

Tablica 3. Oznake opasnosti i upozorenja za limunsku kiselinu – monohidrat prema koncentraciji (izvor: Merck KGaA, 2011., Safety data sheet for Citric Acid Monohydrate)
Table 3 Hazard symbols and risk phrases for Citric Acid Monohydrate based on concentration (source: Merck KGaA, 2011, Safety data sheet for Citric Acid Monohydrate)

Koncentracija *Concentration*	**Oznaka opasnosti** *Hazard symbol*	**Opis oznake opasnosti** *Description of hazard symbol*	**R-oznaka upozorenja** *R risk phrase*	**Opis oznake upozorenja** *Description of risk phrase*
≥ 99 %	Xi	nadražujuće *Irritating*	R36	R36-nadražuje oči *Irritating to eyes*

sapnice koje su korodirale i imale nakupine kamenca, dvije sapnice koje su imale samo nakupine kamenca te po jedna sapnica koja nije bila u uporabi, a na njoj su utvrđivane promjene dimenzija nakon tretiranja (provjera utječe li izloženost određenoj koncentraciji i temperaturi otopine te određenom vremenu tretiranja korozivno na tijelo sapnice). Promjene dimenzija provjeravane su umjerenim mikrometrom s točnošću mjerenja $d = 0{,}01$ mm i mjernim rasponom 0 – 25 mm.

Vodena otopina sobne temperature

Postupak 1:
a) 5 minuta u 3 %-tnoj vodenoj otopini limunske kiseline sobne temperature,
b) 10 minuta u 3 %-tnoj vodenoj otopini limunske kiseline sobne temperature.

Postupak 2:
a) 5 minuta u 5 %-tnoj vodenoj otopini limunske kiseline sobne temperature,
b) 10 minuta u 5 %-tnoj vodenoj otopini limunske kiseline sobne temperature.

Postupak 3:
a) 5 minuta u 10 %-tnoj vodenoj otopini limunske kiseline sobne temperature,
b) 10 minuta u 10 %-tnoj vodenoj otopini limunske kiseline sobne temperature.

Postupak 4:
a) 5 minuta u 15 %-tnoj vodenoj otopini limunske kiseline sobne temperature,
b) 10 minuta u 15 %-tnoj vodenoj otopini limunske kiseline sobne temperature.

Provrela vodena otopina (prokuhavanje)

Postupak 5:
a) 5 minuta u provreloj 3 %-tnoj vodenoj otopini limunske kiseline,
b) 10 minuta u provreloj 3 %-tnoj vodenoj otopini limunske kiseline.

Postupak 6:
a) 5 minuta u provreloj 5 %-tnoj vodenoj otopini limunske kiseline,
b) 10 minuta u provreloj 5 %-tnoj vodenoj otopini limunske kiseline.

Postupak 7:
a) 5 minuta u provreloj 10 %-tnoj vodenoj otopini limunske kiseline,
b) 10 minuta u provreloj 10 %-tnoj vodenoj otopini limunske kiseline.

Postupak 8:
a) 5 minuta u provreloj 15 %-tnoj vodenoj otopini limunske kiseline,
b) 10 minuta u provreloj 15 %-tnoj vodenoj otopini limunske kiseline.

Radi lakšeg praćenja i usporedbe dobivenih rezultata, utvrđeno je šest stupnjeva ocjenjivanja uspješnosti čišćenja (tabl. 4) koji su primijenjeni za vizualnu ocjenu očišćenosti od kamenca i korozije. Za ocjenjivanje je također utvrđeno šest stupnjeva kvalitete raspršivanja vodene magle očišćenih sapnica (tabl. 5).

Za pripremu otopine upotrijebljena je destilirana voda i *ACIDUM CITRICUM – monohydricum*. Nakon čišćenja sve su sapnice testirane u klasičnim komornim sušionicama. Djelovanje limunske kiseline na očišćenost sapnica te kvalitetu raspršivanja vodene magle ocijenile su dvije stručne osobe istodobno, i to na temelju vizualnih opažanja.

Tablica 4. Ocjene uspješnosti čišćenja
Table 4 Assessment of cleaning efficiency

Ocjena *Assessment*	**Opis ocjene** *Assessment description*
0	nije očišćeno *No cleaning*
1	blago površinsko čišćenje *Slight surface cleaning*
2	djelomično čišćenje *Partial cleaning*
3	zadovoljavajuće čišćenje *Satisfactorily cleaning*
4	vrlo dobro čišćenje *Very good cleaning*
5	potpuno čišćenje *Complete cleaning*

Tablica 5. Ocjena kvalitete raspršivanja vodene magle
Table 5 Quality assessment of water mist dispersion

Ocjena *Assessment*	**Opis ocjene** *Assessment description*
0	nema raspršivanja *No dispersion*
1	loše raspršivanje uz krupne mlazove *Poor dispersion with massive jets*
2	loše raspršivanje uz krupne kapi *Poor dispersion with big drops*
3	dobro raspršivanje uz manje nedostatke *Good dispersion with minor flaws*
4	odlično raspršivanje uz malo slabiji intenzitet magle *Excellent dispersion with a little weaker mist intensity*
5	odlično raspršivanje *Excellent dispersion*

3. REZULTATI
3 RESULTS

U tablici 6. navedeni su rezultati tretiranja metalnih sapnica otopinom limunske kiseline sobne temperature koji se odnose na kvalitetu očišćenosti od kamenca i korozije, te na kvalitetu raspršivanja vodene magle. U tablici 7. navedeni su rezultati tretiranja metalnih sapnica otopinom limunske kiseline u provrelom stanju, a odnose se na kvalitetu očišćenosti od kamenca i korozije, te na kvalitetu raspršivanja vodene magle.

3.1. Tretiranje vodenom otopinom limunske kiseline sobne temperature
3.1 Treatment in the aqueous solution of citric acid at ambient temperature

Rezultati istraživanja pokazuju da tretiranje sapnica u vodenoj otopini limunske kiseline sobne temperature koncentracije 5 – 10 % nema učinka bez obzira na trajanje obrade. Tek pri koncentraciji 15 % otopina blago površinski očisti kamenac, ali u raspršivanju vodene magle nema poboljšanja.

Tablica 6. Rezultati tretiranja vodenom otopinom limunske kiseline sobne temperature
Table 6 Results of treatment in the aqueous solution of citric acid at ambient temperature

Red. br. *Ordinal*	**Oznaka uzorka** *Sample designat.*	**Faza** *Phase*	**Vrijeme tretiranja** *Time of treatment* min	**Koncentracija** *Concentration* %	**Ocjena uklanjanja kamenca** *Assessment of limescale removal*	**Ocjena uklanjanja korozije** *Assessment of corrosion removal*	**Opis kvalitete raspršivanja vodene magle** *Description of quality of water mist dispersion*
1.	kam-1	I. a)	5	3	0	-	0
2.	kam-2	I. a)	5	3	0	-	0
3.	kor-1	I. a)	5	3	0	0	0
4.	kor-2	I. a)	5	3	0	0	0
5.	kam-3	I. b)	10	3	0	-	0
6.	kam-4	I. b)	10	3	0	-	0
7.	kor-3	I. b)	10	3	0	0	0
8.	kor-4	I. b)	10	3	0	0	0
9.	kam-5	II. a)	5	5	0	-	0
10.	kam-6	II. a)	5	5	0	-	0
11.	kor-5	II. a)	5	5	0	0	0
12.	kor-6	II. a)	5	5	0	0	0
13.	kam-7	II. b)	10	5	0	-	0
14.	kam-8	II. b)	10	5	0	-	0
15.	kor-7	II. b)	10	5	0	0	0
16.	kor-8	II. b)	10	5	0	0	0
17.	kam-9	III. a)	5	10	0	-	0
18.	kam-10	III. a)	5	10	0	-	0
19.	kor-9	III. a)	5	10	0	0	0
20.	kor-10	III. a)	5	10	0	0	0
21.	kam-11	III. b)	10	10	0	-	0
22.	kam-12	III. b)	10	10	0	-	0
23.	kor-11	III. b)	10	10	0	0	0
24.	kor-12	III. b)	10	10	0	0	0
25.	kam-13	IV. a)	5	15	1	-	0
26.	kam-14	IV. a)	5	15	1	-	0
27.	kor-13	IV. a)	5	15	1	0	0
28.	kor-14	IV. a)	5	15	1	0	0
29.	kam-15	IV. b)	10	15	1	-	0
30.	kam-16	IV. b)	10	15	1	-	0
31.	kor-15	IV. b)	10	15	1	0	0
32.	kor-16	IV. b)	10	15	1	0	0

kam - sapnice koje ne zadovoljavaju uvjete uporabe, a na sebi imaju samo naslage kamenca / *Nozzles not adequate for use, having only deposits of limescale;* kor – sapnice koje ne zadovoljavaju uvjete uporabe, na sebi imaju naslage kamenca, ali su tijekom duljeg stajanja i korodirale / *Nozzles not adequate for use, having deposits of limescale and corrosion as they were out of order for long*

3.2. Tretiranje provrelom vodenom otopinom limunske kiseline
3.2 Treatment in the boiled aqueous solution of citric acid

Na slici 1. prikazana je višekratno upotrebljavana sapnica prije čišćenja provrelom vodenom otopinom limunske kiseline, dok je na slici 2. prikazana ista sapnica nakon čišćenja.

Sa sapnica koje su čišćene provrelom vodenom otopinom limunske kiseline koncentracije 3 % u trajanju 5 minuta kamenac je zadovoljavajuće očišćen, korozija je blago površinski očišćena, a sapnice nakon čišćenja odlično raspršuju vodenu maglu, uz malo slabiji intenzitet magle.

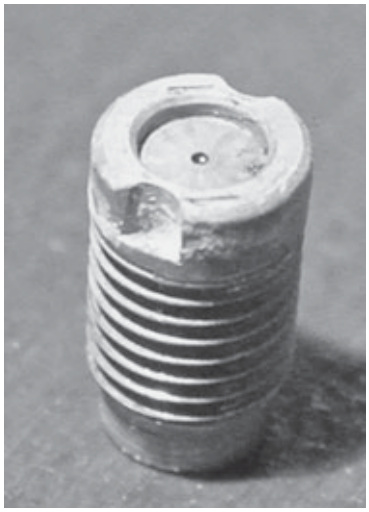
U sapnica tretiranih provrelom vodenom otopinom limunske kiseline koncentracije 3 % u trajanju 10 minuta razina očišćenosti od kamenca i korozije jednaka je kao pri čišćenju 3 %-tnom otopinom u trajanju 5 mi-

Slika 1. Sapnica prije čišćenja
Figure 1 Nozzle before treatment

Tablica 7. Rezultati tretiranja provrelom vodenom otopinom limunske kiseline
Table 7 Results of treatment in the boiled aqueous solution of citric acid

Red. br. *Ordinal*	**Oznaka uzorka** *Sample designat.*	**Faza** *Phase*	**Vrijeme tretiranja** *Time of treatment* min	**Koncentracija** *Concentration* %	**Ocjena uklanjanja kamenca** *Assessment of limescale removal*	**Ocjena uklanjanja korozije** *Assessment of corrosion removal*	**Opis kvalitete raspršivanja vodene magle** *Description of quality of water mist dispersion*
1.	kam-17	V. a)	5	3	3	-	4
2.	kam-18	V. a)	5	3	3	-	4
3.	kor-17	V. a)	5	3	3	1	4
4.	kor-18	V. a)	5	3	3	1	4
5.	kam-19	V. b)	10	3	3	-	5
6.	kam-20	V. b)	10	3	3	-	5
7.	kor-19	V. b)	10	3	3	1	5
8.	kor-20	V. b)	10	3	3	1	5
9.	kam-21	VI. a)	5	5	3	-	5
10.	kam-22	VI. a)	5	5	3	-	5
11.	kor-21	VI. a)	5	5	3	1	5
12.	kor-22	VI. a)	5	5	3	1	5
13.	kam-23	VI. b)	10	5	3	-	5
14.	kam-24	VI. b)	10	5	3	-	5
15.	kor-23	VI. b)	10	5	3	1	5
16.	kor-24	VI. b)	10	5	3	1	5
17.	kam-25	VII. a)	5	10	4	-	5
18.	kam-26	VII. a)	5	10	4	-	5
19.	kor-25	VII. a)	5	10	4	1	5
20.	kor-26	VII. a)	5	10	4	1	5
21.	kam-27	VII. b)	10	10	4	-	5
22.	kam-28	VII. b)	10	10	4	-	5
23.	kor-27	VII. b)	10	10	4	1	5
24.	kor-28	VII. b)	10	10	4	1	5
25.	kam-29	VIII. a)	5	15	5	-	5
26.	kam-30	VIII. a)	5	15	5	-	5
27.	kor-29	VIII. a)	5	15	5	2	5
28.	kor-30	VIII. a)	5	15	5	2	5
29.	kam-31	VIII. b)	10	15	5	-	5
30.	kam-32	VIII. b)	10	15	5	-	5
31.	kor-31	VIII. b)	10	15	5	3	5
32.	kor-32	VIII. b)	10	15	5	3	5

kam - sapnice koje ne zadovoljavaju uvjete uporabe, a na sebi imaju samo naslage kamenca / *Nozzles not adequate for use, having only deposits of limescale;* kor – sapnice koje ne zadovoljavaju uvjete uporabe, na sebi imaju naslage kamenca, ali su tijekom duljeg stajanja i korodirale / *Nozzles not adequate for use, having deposits of limescale and corrosion as they were out of order for long*



Slika 2. Sapnica nakon čišćenja
Figure 2 Nozzle after treatment

nuta, dok se znatnije poboljšanje vidi u raspršivanju vodene magle – ono je odlično. Isti su rezultati postignuti i 5 %-tnom otopinom u trajanju od 5 i 10 minuta.

Sa sapnica čišćenih provrelom vodenom otopinom limunske kiseline koncentracije 10 % u trajanju 5 minuta znatno je poboljšano uklanjanje kamenca, koje je vrlo dobro. Isti su rezultati postignuti i 10 %-tnom otopinom, u trajanju 10 minuta.

Na sapnicama tretiranim vodenom otopinom limunske kiseline koncentracije 15 % u trajanju 5 min poboljšano je uklanjanje kamenca, koji je u potpunosti nestao, te je poboljšana očišćenost od korozije, tj. djelomično je nestala.

Na sapnicama tretiranim vodenom otopinom limunske kiseline koncentracije 15 % u trajanju 10 minuta poboljšano je uklanjanje korozije, koje je zadovoljavajuće.

4. DISKUSIJA
4 DISCUSSION

U sušioničkoj je praksi najveći problem činjenica da se u trenutku pojave problema traži brzo, trenutačno rješenje, bez pokušaja da se shvati mehanizam nastanka problema. Ako se i nađe trenutačno rješenje, problem se ubrzo zaboravi, te se ne vodi nikakva evidencija o uzrocima, mehanizmu nastanka problema ili rješenju. U takvim je uvjetima ponovno pojavljivanje istog problema nakon određenog vremena unaprijed „zajamčeno“ (Welling, 2000). Uvijek je bolje djelovati preventivno na stvaranje naslaga kamenca nego riskirati neodgovarajuće navlaživanje i nemogućnost postizanja parametara sušenja. Postoje različiti načini omekšavanja vode. Osim standardnoga – uz pomoć soli, jedan je od zanimljivijih tretiranje „tvrde vode“ elektromagnetskim poljem permanentnog magneta, pri čemu je dokazano da taj postupak smanjuje sadržaj iona kalcija, što pridonosi smanjenju nastanka tvrdih naslaga kamenca na stijenkama (Gabrielli i dr., 2001). Za uspješnu primjenu magnetskog tretmana „tvrde vode“ izuzetno je bitan i izbor materijala vodovodne cijevi jer je dokazano da su nevodljivi materijali najučinkovitiji za takvu vrstu tretiranja (Alimi, i dr., 2009). Uređaji za magnetski tretman „tvrde vode“ radi suzbijanja taloženja kamenca u uporabi su već dulje od pola stoljeća, a prvi komercijalni uređaj patentiran je u Belgiji 1945. (Vemeiren, 1958). Valja napomenuti da unatoč velikom broju različitih uređaja za magnetsko tretiranje vode koji se nude na tržištu, a što bi se moglo smatrati pokazateljem učinkovitosti magnetskih polja na stvaranje naslaga kamenca, većina neovisnih ispitivanja o performansama uređaja još su dosta kontroverzna (MacAdam i Parsons, 2004).

Iz rezultata dobivenih ovim istraživanjem vidljivo je da čišćenje uzoraka hladnom otopinom limunske kiseline nije dalo značajnije rezultate, najvjerojatnije zbog prekratkog vremena izloženosti otopini, dok je čišćenje uzoraka prokuhavanjem dalo odlične rezultate, čak i pri najmanjoj koncentraciji i najkraćem trajanju. Sve sapnice koje su prokuhavane bile su zadovoljavajuće očišćene i spremne za ponovnu uporabu. Iako se prokuhavanjem u otopinama manjih koncentracija za testirana vremena nisu u potpunosti očistile naslage kamenca s vanjskih stijenki sapnica, njime su u potpunosti pročišćeni prolazni putovi vode unutar sapnica. Pri većim koncentracijama čak je uočena znatnija očišćenost od korozije s površina sapnica. Također je utvrđeno da čišćenje sapnica otopinom limunske kiseline ne smanjuje nazivne dimenzije sapnice, tj. otopina limunske kiseline ne djeluje nagrizajuće na stijenke metalnih sapnica, kako upotrebljavanih, tako i neupotrebljavanih, što je utvrđeno naknadnim pokusom. Postoji mogućnost da se nakon višegodišnjeg tretiranja iste metalne sapnice vodenom otopinom limunske kiseline uoči neznatno nagrizajuće djelovanje na tijelo sapnice, ali bi o tome trebalo provesti daljnja dugotrajna istraživanja. Rukovanje limunskom kiselinom nema štetnih posljedica za osobe koje njome rukuju jer je također poznato da se limunska kiselina upotrebljava u prehrambenoj industriji i u kućanstvima, za konzumaciju. Limunska je kiselina jeftina, dostupna, relativno neopasna, neagresivna i ne nagriza tijelo metalne sapnice.

5. ZAKLJUČAK
5 CONCLUSION

Na temelju rezultata istraživanja i diskusije može se zaključiti da se tvrde naslage kamenca mogu uspješno očistiti provrelom vodenom otopinom limunske kiseline, a da se ne ošteti tijelo metalne sapnice. Iako je ispitivanje provedeno industrijskom limunskom kiselinom, ona je po svom sastavu i koncentraciji identična konzumnoj limunskoj kiselini koja se prodaje u maloprodajnim prehrambenim trgovinama. Zbog niske cijene limunske kiseline pri prokuhavanju je preporučena i uporaba većih koncentracija limunske kiseline u vodenoj otopini kako bi se postiglo potpunije čišćenje u kraćemu vremenskom roku. Limunskom je kiselinom moguće očistiti i plastične sapnice, ali se one ne smiju prokuhavati kako se plastično tijelo sapnica ne bi rastopilo, već ih je potrebno kratkotrajno umakati u kipuću otopinu limunske kiseline. Praktičnom primjenom rezultata ovog istraživanja u industrijskim uvjetima potvrđeni su svi navedeni zaključci.

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6. LITERATURA
6 REFERENCES

1. Alimi, F.; Tlili, M.M.; Ben Amor, M.; Maurin, G.; Gabrielli, C., 2009: Effect of magnetic water treatment on calcium carbonate precipitation: Influence of the pipe material. Chemical Engineering and Processing, 48 (8): 1327-1332 http://dx.doi.org/10.1016/j.cep.2009.06.008.
2. Baker, J.S.; Judd, S.J.; Parsons, S.A., 1997: Antiscale magnetic pretreatment of reverse osmosis feedwater. Desalination, 110 (1-2): 151-166 http://dx.doi.org/10.1016/S0011-9164(97)00094-5.
3. Dadić, Ž., 2001: Priručnik o temeljnoj kakvoći vode u Hrvatskoj. Hrvatski zavod za javno zdravstvo, Zagreb, Hrvatska.
4. Gabrielli, C.; Jaouhari, R.; Maurin, G.; Keddam, M., 2001: Magnetic water treatment for scale prevention. Water Research, 35 (13): 3249-3259 http://dx.doi.org/10.1016/S0043-1354(01)00010-0.
5. Krpan, J., 1965: Sušenje i parenje drva. Šumarski fakultet Sveučilišta u Zagrebu, Zagreb, Hrvatska.
6. Legrand, L.; Leroy, P., 1990: Prevention of Corrosion and Scaling in Water Supply Systems. Ellis Horwood Series in Water and Waste Water Technology, New York, USA.
7. MacAdam, J.; Parson, A., 2004: Calcium carbonate scale formation and control. Reviews in Environmental Science and Bio / Technology. 3 (2): 159-169 http://dx.doi.org/10.1007/s11157-004-3849-1.
8. Pervan, S., 2000: Priručnik za tehničko sušenje drva. Sand, Zagreb, Hrvatska.
9. Šivak, M., 2002: Tehnologija pripreme tehničkih voda u termoenergetici. N.D.M.Š., Zagreb, Hrvatska.

10. Vermeiren, T., 1958: Magnetic treatment of liquids for scale and corrosion prevention. Corrosion Technology. 5: 215-219.
11. Welling, J., 2000: Timber Drying Research – Industrial Needs and Scientific Expectations. 2nd Workshop of COST Action E15 „Quality Drying of Hardwood“, 11-13 September 2000, Sopron, Hungary.
12. *** Zakon o zaštiti na radu (Narodne Novine, br. 59/96., 94/96., 114/03., 100/04., 86/08., 116/08. i 75/09.).
13. *** Pravilnik o razvrstavanju, označavanju, obilježavanju i pakiranju opasnih kemikalija – Prilog 1 (Narodne Novine, br. 23/08. i 64/09.).
14. *** Merck KGaA, 2011: Safety data sheet for Citric acid monohydrate. Darmstadt, Germany.

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Convective Drying of Beech Lumber without Color Changes of Wood

Konvektivno sušenje bukovih piljenica bez promjene boje drva

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ABSTRACT • *This paper presents the results of analyzing the influence of suggested regimes of chamber drying of beech lumber with the thickness h = 40 mm, h = 60 mm and h = 80 mm from the initial moisture content W_p = 70 % to the final moisture content W_k = 8 %. The regimes ensure the preservation of the natural color of the wood.*
The study results show that the drying of beech lumber according to the suggested regimes causes no changes in the chromophoric compounds of the wood and the beech lumber preserves its original white-yellow color. Quality parameters of the dried lumber, such as: difference between the average final moisture content and the required final moisture content, and the range of the final moisture and moisture gradient in dried beech lumber, classify this dried lumber into the first quality class. The suggested regimes for drying beech lumber using hot air in the temperature range t_s = 37 ÷ 65 °C has a negative impact on the duration of the drying process. In comparison with the regimes of beech lumber drying according to ON 49 0651, carried out at temperatures t = 60 ÷ 80 °C, the duration of drying beech lumber with the thickness h = 40 mm according to the suggested regime is 1.9 times longer, the duration of drying beech lumber with the thickness h = 60 mm is 2.3 times longer and the duration of drying beech lumber with the thickness h = 80 mm is 2.9 times longer. The specific heat energy consumption of beech lumber with the initial moisture content W_p = 70 % to the final moisture content W_k = 8 % in a chamber type KWC 121, according to the suggested regimes, is equals to Q_{TZN} = 514.46 kWh·m^{-3} for the thickness h = 40 mm, Q_{TZN} = 557.62 kWh·m^{-3} for lumber with the thickness h = 60 mm, and Q_{TZN} = 643.16 kWh·m^{-3} for lumber with the thickness h = 80 mm. The specific heat energy consumption needed for the drying of 1 m³ of beech lumber with the thickness h = 60 mm according to the suggested regime is by 26.89% higher than the specific heat energy consumption used to dry beech lumber of the same thickness according to the regime of beech lumber drying by Vzduchotechnika a.s. which does not preserve the natural color of the wood.

Keywords: *beech lumber, convective drying, regime of drying, color of wood*

SAŽETAK • *U radu se prezentiraju rezultati analize utjecaja predloženih režima sušenja bukovih piljenica debljine h = 40 mm, h = 60 mm i h = 80 mm od početnog sadržaja vodet W_p = 70 % do konačnog sadržaja vode W_k = 8 % u komornim sušionicama. Predloženi režimi osiguravaju zadržavanje prirodne boje drva. Rezultati studije pokazuju da sušenje bukova drva prema predloženim režimima sušenja ne uzrokuje promjene kromoforičnih sastojaka drva pa bukove piljenice zadržavaju svoju originalnu bijeložutu boju. Parametri kvalitete osušenog drva kao što su razlika između prosječnoga konačnog sadržaja vode i traženoga konačnog sadržaja vode, raspon konačnih*

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sadržaja vode te gradijent vlažnosti osušenih bukovih piljenica svrstavaju piljenice osušene predloženim režimom u I. stupanj kvalitete. Provedba predloženih režima sušenja bukovih piljenica upotrebom vrućeg zraka temperature u rasponu 37 – 65 °C ima negativan utjecaj na trajanje procesa sušenja. U usporedbi s režimima sušenja bukovih piljenica prema standardu ON 49 0651, koji se provode pri temperaturama 60 – 80 °C, trajanje procesa sušenja bukovih piljenica debljine 40 mm predloženim je režimom 1,9 puta dulje, za piljenice debljine 60 mm proces sušenja traje 2,3 puta dulje, a za piljenice debljine 80 mm 2,9 puta dulje. Specifična potrošnja toplinske energije za sušenje bukovih piljenica predloženim režimom sušenja s početnog sadržaja vode 70 % na konačni sadržaj vode 8 % u komori tipa KWC 121 iznosi Q_{TZN} = 514,46 kWh·m^{-3} za piljenice debljine h = 40 mm, Q_{TZN} = 557,62 kWh·m^{-3} za piljenice debljine h = 60 mm, te Q_{TZN} = 643,16 kWh·m^{-3} za piljenice debljine h = 80 mm. Specifična je potrošnja toplinske energije potrebna za sušenje 1 m^3 bukovih piljenica debljine h = 60 mm primjenom predloženih režima sušenja 26,89 % veća od specifične potrošnje toplinske energije za sušenje bukovih piljenica jednake debljine prema režimu sušenja bukovih piljenica koju primjenjuje Vzduchotechnika a.s., a koja nije usmjerena na očuvanje prirodne boje drva.

Ključne riječi: *bukove piljenice, konvektivno sušenje, režim sušenja, boja drva*

1 INTRODUCTION
1. UVOD

Wood drying belongs to the basic technological operations of wood processing. This technological process is based on considerably complicated hydro-thermal process and despite the noticeable effort of scientists and technologists, it is not yet fully clarified.

The drying of beech lumber carried out in chambers according to the regimes of the companies: Hildebrandt GmbH, Incomac S.R.L., Vzduchotechnika a.s., and Mühlböck GmbH is commonly realized at temperatures t = 60 – 80 °C. In beech wood, the hydro-thermal process at these temperatures not only removes water from the wood, but also develops some chemical reactions such as partial hydrolysis of the hemicelluloses and the extraction of water-soluble substances (Bučko, 1995; Trebula and Bučko, 1996; Halaj, 1999; Dzurenda and Deliiski, 2000; Kačík, 2001; Laurova *et al*, 2004), which cause irreversible color changes of wood. One such change is from the original white-yellow color of the beech wood to a dull brown-pink shade. The extent of the change of wood color during the hydro-thermal treatment of wood, Deliiski (1991) is defined by the criterion of color homogenization of wood S_{FH}, which is equal to the integral area of the function of temperature change during the hydro-thermal treatment of wood. The unit of this criterion is a thermosecond (K·s). The change of the color shade of beech wood from the original white-yellow to brown-pink shade occurs after surpassing the limit for the color homogenization criterion $S_{FH} \leq 1.2 \times 10^7$ K·s (Deliiski, 2003).

To eliminate this imperfection, special regimes were created for convective drying of beech wood in chambers, which preserve the natural color of the beech wood. The goal of this work is to present the suggested regimes for drying beech lumber with the thickness h = 40 mm, h = 60 mm and h = 80 mm, from W_p = 70 % to W_k = 8 %, in chambers and their evaluation from the aspects of quality of dried lumber, extent of color change (Deliiski and Dzurenda, 2003) and their specific heat consumption.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The parameters of the regimes for drying beech lumber with the thickness h = 40 mm, h = 60 mm and h = 80 mm, from W_p = 70 % to W_k = 8 %, which cause no change of the natural color of the wood, are shown in Table 1.

At the end of lumber drying, when the wood moisture content reaches a value of approximately 20%, conditioning is included for partial decreasing of the moisture gradient. Conditioning is carried out by an increase of the relative humidity.

The drying of beech lumber with the thickness h = 40 mm, h = 60 mm and h = 80 mm, according to individual regimes, was carried out in chamber type KWC 121 manufactured by Vzduchotechnika a.s. Nové Mesto nad Váhom.

The quality of the drying process of beech lumber is evaluated by drying gradient U defined as the quotient of the average moisture content of the lumber subjected to drying and equilibrium moisture content throughout the process.

After the completion of the drying process, a quality check of the dried lumber was performed on 8 samples with the determination of the following parameters: difference between the average final moisture content and the required final moisture content, fluctuation of the final moisture content, moisture gradient, and change of wood color.

The difference w_0 between the average final moisture content and the required final moisture content (in %) was quantified using the following equation:

$$W_0 = \frac{\sum_{i=1}^{n} W_{ik}}{n} - W_k , \qquad (1)$$

where:

n – number of samples / *broj uzoraka*

W_{ik} – average final moisture content of samples / *prosječni konačni sadržaj vode u uzorcima*, %;

W_k – required final moisture content of samples / *potrebni konačni sadržaj vode u uzorcima,* %.

Table 1 Parameters of the regimes for drying beech lumber from W_p = 70 % to W_k = 8 %, preserving the original wood color, depending on the lumber thickness
Tablica 1. Parametri režima sušenja bukovih piljenica od W_p = 70 % do W_k = 8 %, koji omogućuju očuvanje prirodne boje drva, ovisno o debljini piljenica

Lumber thickness / *Debljina piljenica*	h = 40 mm			h = 60 mm			h = 80 mm		
Phase of drying / *Faza sušenja*	t	Δt	τ	t	Δt	τ	t	Δt	τ
	°C	°C	h	°C	°C	h	°C	°C	h
Initial heating / *Početno zagrijavanje*	43	3	5	42	3	8	41	3	12
70 – 45	38	5	77	37	5	133	37	5	228
45 – 35	40	5.5	29	39	5	82	39	4.5	143
35 – 25	44	7.5	72	43	7	123	42	6.5	217
25 – 20	48	9.5	55	47	9	97	46	8.5	166
Conditioning / *Kondicioniranje*	48	5.5	4	47	5	6	46	4.5	9
20 – 15	54	14	64	53	13.5	109	52	13.5	189
15 – 10	61	18.5	88	60	18	152	59	17.5	263
10 – 8	64	23	42	63	20	71	63	19	124
Treatment / *Tretiranje*	64	6	9	63	5.5	13	63	5.5	18
Cooling / *Hlađenje*			5			8			12

The range of final moisture content of the dried lumber was calculated as the difference between maximum and minimum values of the moisture content in dried samples according to the equation:

$$W_{k0} = W_{max} - W_{min}, \quad (2)$$

where:
W_{max} – maximum moisture content in samples / *najveći sadržaj vode u uzorcima*, %;
W_{min} – minimum moisture content in samples / *najmanji sadržaj vode u uzorcima*, %.

The moisture gradient ΔW (in %) was calculated as the difference between the moisture content of the middle layer of the samples and the average moisture content of both surface layers:

$$\Delta W = W_c - W_{pov}, \quad (3)$$

where:
W_c – moisture content of the sample middle layer / *sadržaj vode u srednjem sloju uzoraka*, %;
W_{pov} – moisture content of the sample surface layers / *sadržaj vode na površini uzoraka*, %.

The color of wood on the surface of beech lumber was measured by a colorimeter Color Reader CR-10, which determines the color by a set of values in the color coordinate system CIE – L^*a^*b. The principle of measuring with this colorimeter is based on the determination of the following parameters: L^*, which quantifies the lightness of the color from 100 for white color to 0 for black; a^*, which quantifies the chromatic coordinate of color shade between red and green; b^*, which quantifies the chromatic coordinate of color shade between yellow and blue.

The change of the color of beech wood subjected to drying was determined by the size of changes of the individual coordinates in the color coordinate system before drying and also on a planed surface of wood after drying as well as by the size of color deviation $\Delta E_{a.b}$ according to CIE (1986), presented by the equation:

$$\Delta E_{ab} = \sqrt{\left(L_2^* - L_1^*\right)^2 + \left(a_2^* - a_1^*\right)^2 + \left(b_2^* - b_1^*\right)^2}, \quad (4)$$

where:
L^* – color lightness / *svjetlina boje;*
a^* – coordinate of color shade between red and green / *koordinata nijanse boje između crvene i zelene;*
b^* – coordinate of color shade between yellow and blue / *koordinata nijanse boje između žute i plave.*

L_1^*, a_1^*, b_1^* represent the values before drying and L_2^*, a_2^*, b_2^* represent the values after drying.

The specific heat consumption required for drying beech lumber with the thickness h = 40 mm, h = 60 mm and h = 80 mm in chamber type KWC 121 according to the suggested regimes is determined as technically reasonable norms (Q_{TZN}) via a mathematical model for technical calculation of normative heat consumption for lumber drying in chambers (Dzurenda and Deliiski, 2009). The normative specific heat energy consumption (in kWh·m^{-3}) for lumber drying in chambers is presented by the equation:

$$Q_{TZN} = \frac{Q_W + Q_V + Q_A + Q_L + Q_{HG} + Q_S}{V_D}, \quad (5)$$

where:
Q_W – heat energy, necessary for the heating of lumber in chambers / *toplinska energija za zagrijavanje piljenica*, kWh;
Q_V – heat energy, necessary for the heating of wet air in the drying chamber and its moistening during the phase of heating and final treatment / *toplinska energija za zagrijavanje vlažnog zraka u sušionici tijekom faze inicijalnog zagrijavanja, kondicioniranja i obrade*, kWh;
Q_A – heat energy, necessary for the heating of the construction of drying chambers / *toplinska energija za zagrijavanje konstrukcije sušionice*, kWh;
Q_L – heat energy, necessary for the heating of air in the drying chamber for the purpose of water evaporation from wood / *toplinska energija za zagrijavanje zraka u sušionici radi isparavanja vode iz drva*, kWh;
Q_{HG} – heat energy, necessary for the release of hygroscopically bounded water from wood / *toplinska energija za oslobađanje higroskopski vezane vode iz drva*, kWh;
Q_S – heat energy, necessary for the covering of heat losses of the drying chamber / *toplinska energija za nadoknadu gubitaka topline sušionice*, kWh;

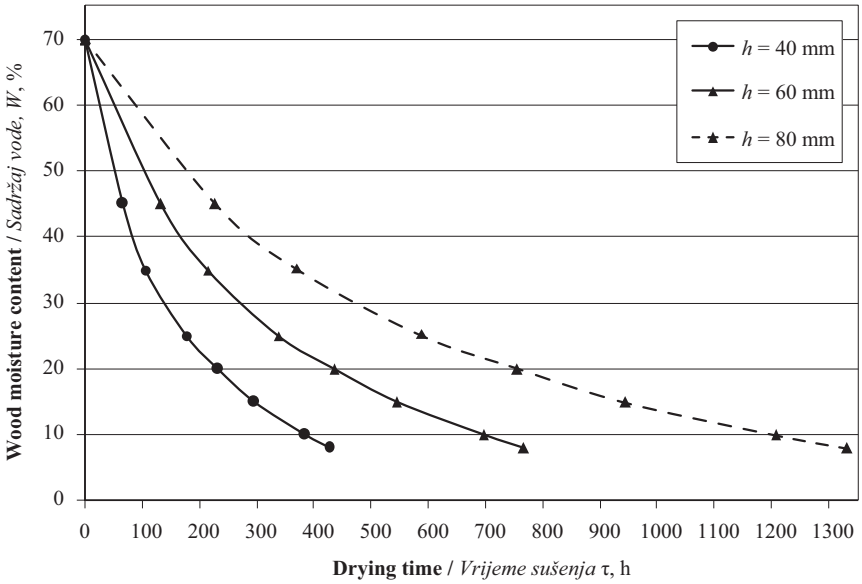

Figure 1 Change in the average moisture content of the lumber during the suggested regimes, depending on the thickness *h*
Slika 1. Promjena prosječnog sadržaja vode u piljenicama tijekom sušenja predloženim režimima, ovisno o debljini piljenica

V_D – volume of wood subjected to drying / *obujam drva koje se suši*, m^3.

3 RESULTS
3. REZULTATI

The change in the average moisture content of the lumber with the thickness h = 40 mm, h = 60 mm and h = 80 mm during the suggested drying regimes is shown in Fig.1

The change in the drying gradient of the suggested regimes depending on the phase of the regime and on lumber thickness shown in Fig. 2.

The initial and final moisture content of the dried samples, the values of the parameters of color coordinates L^*, a^*, and b^* of dried samples before and after drying, as well as the size of color deviations of beech wood ΔE_{ab} caused by the drying process are shown in Tables 2, 3 and 4.

Table 5 shows the results of the analysis, by which the quality was evaluated of dried beech lumber based on the difference between the average final moisture content and the required final moisture content, fluctuation in the final moisture content and moisture gradient of lumber.

Based on the comparison of the measured values of deviations of the average final moisture content from the required final moisture content, the range of the final moisture content of the dried beech lumber and the moisture gradient in the dried lumber with the values of quality characteristics of individual quality classes, it can be concluded that the dried beech lumber with the thickness h = 40 mm fulfills the criteria of the first quality class according to the analysis of the following quality characteristics: W_0 = 0.3 % ≤ 0.5 %, W_{k0} = 1.0 % ≤ 2.0 % a ΔW = 0.8 ÷ 1.3 % ≤ 1. 5 %.

Analogously, the quality evaluation of the dried beech lumber with the thickness h = 60 mm with the quality

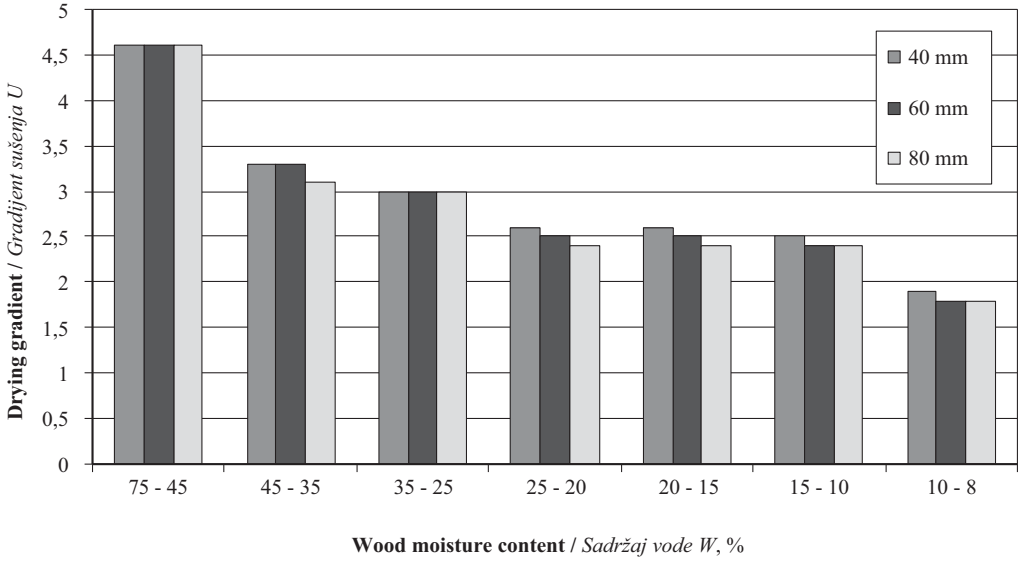

Figure 2 Change in the drying gradient of the suggested regimes depending on wood moisture content and lumber thickness
Slika 2. Promjena gradijenta sušenja za predložene režime sušenja ovisno o sadržaju vode i debljini piljenica

Table 2 Changes in moisture content, color coordinates L^*, a^*, and b^* of beech lumber with the thickness h = 40 mm at the beginning and at the end of drying, and the size of color deviation of wood ΔE_{ab} during the drying process
Tablica 2. Promjene sadržaja vode, koordinata boje L^*, a^* i b^* za bukove piljenice debljine h = 40 mm na početku i na kraju sušenja te veličina promjene boje ΔE_{ab} tijekom procesa sušenja

Sample *Uzorak*	**Moisture content of lumber** *Sadržaj vode u piljenicama*	**Color coordinates** / *Koordinate boje*			ΔE_{ab}
		L^*	a^*	b^*	
1	W_p = 70.3 %	71.8	9.2	21.9	0.9
	W_k = 7.9 %	72.3	8.8	22.6	
Change of color coordinates / *Promjena koordinata boje*		0.5	- 0.4	0.7	
2	W_p = 71.6 %	70.7	9.1	21.6	1.0
	W_k = 8.3 %	71.3	8.8	22.4	
Change of color coordinates / *Promjena koordinata boje*		0.6	- 0.3	0.8	
3	W_p = 70.8 %	68.5	14.1	28.6	1.3
	W_k = 8.2 %	69.4	13.5	29.3	
Change of color coordinates / *Promjena koordinata boje*		0.9	- 0.6	0.7	
4	W_p = 73.2 %	70.8	10.0	22.6	1.3
	W_k = 8.9 %	71.2	9,1	23.4	
Change of color coordinates / *Promjena koordinata boje*		0.4	- 0.9	0.8	
5	W_p = 72.5 %	69.6	11.2	24.8	1.1
	W_k = 8.6 %	70.3	10.5	25.2	
Change of color coordinates / *Promjena koordinata boje*		0.7	- 0.7	0.4	
6	W_p = 70.5 %	72.1	9.6	23,7	1.4
	W_k = 8.0 %	72.7	8.7	24.6	
Change of color coordinates / *Promjena koordinata boje*		0.6	-0.9	0.9	
7	W_p = 71.8 %	69.8	11.7	25.8	1.2
	W_k = 8.4 %	70.6	11.0	26.4	
Change of color coordinates / *Promjena koordinata boje*		0.8	- 0.7	0.6	
8	W_p = 71.2 %	66.8	11.0	22.1	1.0
	W_k = 8.1 %	67.4	10.5	22.8	
Change of color coordinates / *Promjena koordinata boje*		0.6	- 0.5	0.7	

characteristics $W_0 = 0.4\% \leq 0.5$ %, $W_{k0} = 1.5$ % ≤ 2.0 % a $\Delta W = 0.6 \div 2.3$ % $\leq$ 2. 5 %, as well as the dried beech lumber with the thickness h = 80 mm with the quality characteristics $W_0 = 0.4$ % ≤ 0.5 %, $W_{k0} = 1.3$ % ≤ 2.0 % a $\Delta W = 1.8 \div 2.3$ % ≤ 2.4 %, fulfill the criteria for placing the dried beech lumber into the first quality class.

During the drying process, the color coordinates of dried samples of beech lumber with the thickness h = 40 mm, as well as h = 60 mm and h = 80 mm have shown slight differences in the form of increasing the whiteness of the beech wood by $\Delta L^* = 0.4 \div 1.2$, decreasing of coordinate a^*, which describes the range of color shades between red and green color by $\Delta a^* = 0.3 \div 1.3$ and an increasing of coordinate b^*, which describes the range of color shades between yellow and blue color by $\Delta b^* = 0.1 \div 0.9$.

The total changes of color differences of beech wood in the drying process $\Delta E_{ab} = 0.8 \div 1.6$ belong to the interval of color difference $\Delta E_{ab} \leq 2$, also marked as "inconsiderable changes of the color".

Table 7 illustrates the values of the total specific heat energy consumptions and the heat energy consumptions of individual items of the balance of the drying process of lumber with the thickness h = 60 mm, according to the suggested regime and the regime for drying beech lumber of Vzduchotechnika a.s. in chamber type KWC 121 from moisture content W_p = 70 % to W_k = 8 %, at initial temperature of the wood t_d = 10 °C and the average air temperature near the drying chamber t_o = 10 °C.

4 DISCUSSION
4. RASPRAVA

According to the specification of the temperatures and psychrometric differences of the drying air in the suggested regimes of convective drying of beech lumber in chambers, according to the categorization of drying regimes (Kollmann, 1955; Trebula, 1989) these regimes are classified to the so-called regimes with rising temperature and decreasing relative humidity of the drying environment.

From the range of values of the drying gradient $U = 4.6 \div 3.3$, during the drying of beech lumber with the thickness h = 40 mm and h = 60 mm, it can be concluded that from the beginning of the drying to reaching the average moisture content W = 35 %, despite low temperature of the drying air, the drying regime can be considered as hard with the probability of creating a moisture gradient along the lumber section. A similar statement also applies to the drying gradient $U = 4.6 \div 3.1$ during the drying of beech lumber with the thickness h = 80 mm.

Table 3 Changes in moisture content, color coordinates L^*, a^*, and b^* of beech lumber with the thickness h = 60 mm at the beginning and at the end of drying, and the size of color deviation of wood ΔE_{ab} during the drying process
Tablica 3. Promjene sadržaja vode, koordinata boje L^*, a^* i b^* za bukove piljenice debljine h = 60 mm na početku i na kraju sušenja te veličina promjene boje ΔE_{ab} tijekom procesa sušenja

Sample *Uzorak*	**Moisture content of lumber** *Sadržaj vode u piljenicama*	**Color coordinates** / *Koordinate boje*			ΔE_{ab}
		L^*	a^*	b^*	
1	W_p = 70.9 %	69.2	11.2	25.2	1.2
	W_k = 8.5 %	69.8	10.2	25.3	
Change of color coordinates / *Promjena koordinata boje*		0.6	-1.0	0.1	
2	W_p = 71.8 %	70.8	8.7	21.8	0.9
	W_k = 9.2 %	71.1	8.3	22.6	
Change of color coordinates / *Promjena koordinata boje*		0.3	- 0.4	0.8	
3	W_p = 69.1 %	72.1	9.6	25.3	1.3
	W_k = 7.7 %	72.7	8.8	26.1	
Change of color coordinates / *Promjena koordinata boje*		0.6	- 0.8	0.8	
4	W_p = 70.8 %	69.4	10.5	22.8	1.3
	W_k = 8.6 %	70.2	9.9	23.6	
Change of color coordinates / *Promjena koordinata boje*		0.8	- 0.6	0.8	
5	W_p = 70.7 %	69.9	9.2	22.3	1.4
	W_k = 8.4 %	71.1	8.6	22.8	
Change of color coordinates / *Promjena koordinata boje*		1.2	- 0.6	0.5	
6	W_p = 70.7%	72.2	10.1	26.0	1.1
	W_k = 8.2 %	72.7	9.6	26.8	
Change of color coordinates / *Promjena koordinata boje*		0.5	- 0.5	0.8	
7	W_p = 71.1 %	69.6	11.0	21.7	1.1
	W_k = 8.4 %	70.2	10.3	22.3	
Change of color coordinates / *Promjena koordinata boje*		0.6	- 0.7	0.6	
8	W_p = 70.8 %	64.5	11.6	24.8	1.3
	W_k = 8.3 %	65.3	10.9	25.1	
Change of color coordinates / *Promjena koordinata boje*		0.8	- 0.7	0.3	

From the average moisture content W = 35 % up to the end of the drying process, the parameters of the drying medium ensure a finer drying of beech lumber. Despite this, the goal of the authors to suggest drying regimes that cause no change in the color of beech lumber while reaching the topmost quality of dried material is validated by the results of the qualitative checks made at the end of drying. According to the results of these checks, the beech lumber dried in chamber type KWC 121 had the natural white-yellow color and the moisture gradient $\Delta W \leq 0.8 \div 1.3$ % for lumber with the thickness h = 40 mm, $\Delta W \leq 0.6 \div 2.3$ % for lumber with h = 60 mm, and $\Delta W \leq 1.8 \div 2.4$ % for lumber with h = 80 mm.

The difference between the suggested regimes and the classical regimes for convective beech lumber drying in chambers developed by the companies Hildebrandt GmbH, Incomac S.R.L., Vzduchotechnika a.s., Mühlböck GmbH (carried out at temperatures $t = 60 \div 80$ °C and allowing color change of beech lumber to brown-pink) is that the process of drying beech lumber according to the suggested regimes is carried out at temperatures within the lower temperature range of the classical regimes.

During the removal of free water located in the lumens of beech wood cells, the drying is carried out by hot air with temperature lower than t = 50 °C and psychrometric difference $\Delta t = 5 \div 10$ °C so that the temperature of the cell walls and free water in the lumens do not exceed $t_m \leq 40$ °C. At these temperatures, the conditions for the process of deacetylation of beech wood, and for subsequent hydrolytical solution of polysaccharidic and extractive substances of beech lumber, which cause changes in the chromophoric structure of wood, cannot be fulfilled (Trebula and Bučko, 1996).

The increase of the temperature of the drying medium to $t = 53 \div 65$ °C and the temperature of the wet wood over $t_m \geq 40$ °C are achieved when the average moisture content $W \leq 20$ %. Then due to the absence of free water in the wood, the increased temperature of the drying air does not cause a change in the chromophoric structure of beech wood. This statement is validated by the results of the measuring of changes of beech wood color caused by drying, as well as by the results of works by Klement and Smilek (2010) and Klement *et al.* (2011), who analyzed the influence of the temperature and the method of drying of beech wood on the color shade of the dried beech wood.

The drying process of beech lumber at the lower temperatures compared to the classical regimes for convective drying of beech lumber is characterized by a lon-

Table 4 Changes in moisture content, color coordinates L^*, a^*, and b^* of beech lumber with the thickness h = 80 mm at the beginning and at the end of drying, and the size of color deviation of wood ΔE_{ab} during the drying process
Tablica 4. Promjene sadržaja vode, koordinata boje L^*, a^* i b^* za bukove piljenice debljine h = 80 mm na početku i na kraju sušenja te veličina promjene boje ΔE_{ab} tijekom procesa sušenja

Sample *Uzorak*	**Moisture content of lumber** *Sadržaj vode u piljenicama*	**Color coordinates** / *Koordinate boje*			ΔE_{ab}
		L^*	a^*	b^*	
1	W_p = 72.9 %	69.4	11.4	25.2	1.6
	W_k = 9.2 %	70.2	10.1	25.8	
Change of color coordinates / *Promjena koordinata boje*		0.8	-1.3	0.6	
2	W_p = 71.6 %	70.9	8.5	21.8	0.8
	W_k = 8.4 %	71.4	8.1	22.3	
Change of color coordinates / *Promjena koordinata boje*		0.5	- 0.4	0.5	
3	W_p = 69.5 %	72.2	8.8	23.3	1.3
	W_k = 7.9 %	72.9	8.2	24.1	
Change of color coordinates / *Promjena koordinata boje*		0.7	- 0.8	0.8	
4	W_p = 70.8 %	69.6	9.5	21.8	1.2
	W_k = 8.6 %	70.2	8.9	22.6	
Change of color coordinates / *Promjena koordinata boje*		0.6	- 0.6	0.8	
5	W_p = 71.2 %	70.0	9.6	22.2	1.6
	W_k = 8.2 %	71.1	8.8	23.0	
Change of color coordinates / *Promjena koordinata boje*		1.1	- 0.8	0.8	
6	W_p = 73.2 %	71.2	10.3	26.0	1.3
	W_k = 8.6 %	71.9	9.6	26.8	
Change of color coordinates / *Promjena koordinata boje*		0.7	- 0.7	0.8	
7	W_p = 71.8 %	69.6	11.0	21.5	1.3
	W_k = 8.4 %	70.4	10.3	22.2	
Change of color coordinates / *Promjena koordinata boje*		0.8	- 0.7	0.7	
8	W_p = 70.3 %	68.5	11.6	24.8	1.5
	W_k = 8.0 %	69.4	10.8	25.7	
Change of color coordinates / *Promjena koordinata boje*		0.9	- 0.8	0.9	

Table 5 Evaluation of the quality of dried lumber
Tablica 5. Ocjena kvalitete osušenih piljenica

Quality characteristics *Parametri kvalitete*	**Sample** *Uzorak*	**Thickness of lumber** / *Debljina piljenica*		
		h = 40 mm	h = 60 mm	h = 80 mm
Difference between average final moisture content and required moisture content *Razlika između prosječnoga konačnog sadržaja vode i potrebnog sadržaja vode*	W_0	0. 3 %	0.4 %	0.4 %
Range of the final moisture content *Raspon konačnih sadržaja vode*	W_{k0}	1.0 %	1.5 %	1.3 %
Moisture gradient of lumber *Gradijent vlažnosti piljenica*	ΔW	0.8 ÷ 1.3 %	0.6 ÷ 2.3 %	1.8 ÷ 2.4 %

Table 6 Technically reasonable norm of the specific heat energy consumption for convective drying of beech lumber according to suggested regimes preserving the natural color of wood
Tablica 6. Tehnički opravdana norma specifične potrošnje toplinske energije za konvektivno sušenje bukovih piljenica prema predloženim režimima sušenja uz očuvanje prirodne boje drva

Thickness of dried lumber *Debljina sušenih piljenica*	**Normative heat energy consumption Q_{TZN}, kWh·m^{-3}** *Normativ potrošnje toplinske energije Q_{TZN}, kWh·m^{-3}*
h = 40 mm	514.46
h = 60 mm	557.62
h = 80 mm	643.16

Table 7 Individual items of balance of the specific heat energy consumption used for drying beech lumber with the thickness h = 60 mm in chamber type KWC 121
Tablica 7. Pojedinačne stavke specifične potrošnje toplinske energije upotrijebljene za sušenje bukovih piljenica debljine h = 60 mm u sušionici tipa KWC 121

Items of balance of the specific heat consumption of the drying chamber type KWC 121 *Stavke specifične potrošnje toplinske energije*		**Regimes of beech lumberdrying** *Režimi sušenja bukovih piljenica*			
		Suggested by the authors *Predložene u radu*		Vzduchotechnika a.s	
		Specific heat energy consumption *Specifična potrošnja toplinske energije*			
		kWh·m^{-3}	%	kWh·m^{-3}	%
Heat energy for heating lumber subjected to drying *Toplinska energija za zagrijavanje piljenica*	Q_W	34.68	6.22	53.40	13.10
Heat energy for heating and moistening the air in the drying chamber during the phases of the initial heating, conditioning and treatment (refer to Table 1) *Toplinska energija za zagrijavanje i vlaženje zraka u sušionici tijekom faze inicijalnog zagrijavanja, kondicioniranja i obrade*	Q_V	0.55	0.10	1.59	0.39
Heat energy for heating the construction of the drying chamber *Toplinska energija za zagrijavanje konstrukcije sušionice*	Q_A	13.71	2.46	18.10	4.44
Heat energy for heating f the air in the chamber with the purpose of water evaporation from wood / *Toplinska energija za zagrijavanje zraka u sušionici radi isparavanja vode iz drva*	Q_L	359.35	64.44	237.87	58.35
Heat energy for the release of the hygroscopically bounded water in wood *Toplinska energija za oslobađanje higroskopski vezane vode iz drva*	Q_{HG}	3.96	0.71	3.99	0.98
Heat energy for the covering of heat losses of the drying chamber *Toplinska energija za nadoknadu gubitaka topline sušionice*	Q_S	145.37	26.07	92.72	22.74
Normative specific heat energy consumption $Q_{TZN} = \sum Q_i$ *Normativ specifične potrošnje toplinske energije* $Q_{TZN} = \sum Q_i$		557.62	100.0	407.67	100.0

ger time needed for lumber drying. In comparison with the drying regimes of the company Vzduchotechnika a.s. realized at temperatures t = 60 ÷ 80 °C, the duration of drying beech lumber is 1.9 times longer for the thickness h = 40 mm while preserving the natural color of wood, 2.3 times longer for the thickness h = 60 mm and 2.9 times longer for the thickness h = 80 mm. This fact reflects negatively on the use of the capacity of drying chambers, as shown in works by Drahoš and Viktorin (1975), Pervan (2000), Trebula and Klement (2002), Videlov (2003), Dzurenda and Deliiski (2010).

The convective drying of beech lumber in chamber type KWC 121 according to the suggested regimes is characterized by the normative specific heat consumption of Q_{TZN} = 514.46 kWh·m^{-3} for lumber with the thickness h = 40 mm, Q_{TZN} = 557.62 kWh·m^{-3} for lumber with the thickness h = 60 mm and Q_{TZN} = 643.16 kWh·m^{-3} for lumber with the thickness h = 80 mm.

Comparing the normative specific heat consumption for lumber with the thickness h = 60 mm and the normative specific heat energy consumption for drying beech lumber of the same thickness in chamber type KWC 121 according to the regime of the company Vzduchotechnika a.s., whose value is Q_{TZN} = 557.62 kWh·m^{-3}, it has been determined that in the process of drying beech lumber according to the suggested regime, by which the natural color of beech wood is preserved, 26.89 % more heat is consumed. This amount of increased heat energy consumption is caused by the increased heat consumption for heating the air during water evaporation from wood and for covering the heat losses of the drying chamber, due to the prolonged duration of drying. Comparable results – prolongation of the duration of drying due to the decrease of temperature of the drying medium and the increase of specific heat consumption for drying lumber in drying chambers, can be found in the works of Drahoš and Viktorin (1975), Glijer (1990), Dzurenda (1993), Dzurenda and Deliiski (2004).

5 CONCLUSION
5. ZAKLJUČAK

Based on the studies performed, it can be stated that the drying of beech lumber with the thickness h = 40 mm, h = 60 mm and h = 80 mm from moisture content W_p = 70 % to W_k = 8 % in chambers according to the suggested regimes with temperature range of the drying medium t_s = 37 ÷ 65 °C causes no changes in the chromophoric structure of wood and that beech wood maintains its natural white-yellow color. The addition of the conditioning phase – partial elimination of moisture gradient during the drying process (ΔW = 25 ÷ 20%) reflects positively on the spreading of moisture content along the section of beech lumber at the end of drying, which enables the grading of this dried lumber into the first quality class.

The negative effect of drying beech wood in the lower part of the temperature range of the classical convective drying regimes is the prolonged drying process. In comparison with the drying regimes of beech lumber of the company Vzduchotechnika a.s. carried out at temperatures t = 60 ÷ 80 °C, the duration of drying beech lumber with the thickness h = 40 mm while maintaining the natural color of wood is 2.1 ti-

mes longer and with the thickness h = 80 mm it is 2.9 times longer.

The specific heat consumption of beech lumber in chamber type KWC 121, according to the suggested regimes for drying beech lumber is Q_{TZN} = 514.46 kWh·m^{-3} for the thickness h = 40 mm, Q_{TZN} = 557.62 kWh·m^{-3} for the thickness h = 60 mm and Q_{TZN} = 643.16 kWh·m^{-3} for the thickness h = 80 mm. The normative heat consumption used for drying beech lumber with the thickness h = 60 mm according to the suggested regime is by 26.89 % higher than the specific heat energy consumption used for drying beech lumber with the same thickness according to the regime of the company Vzduchotechnika a.s.

6 REFERENCES
6. LITERATURA

1. Bučko, J., 1995: Hydrolýzne procesy (Hydrolytical processes). Zvolen. Vydavateľstvo TU vo Zvolene. 116 s.
2. Colorimetry. 1986: 2nd Edition, CIE Pub. No. 15.2. Commission Internationale de l'Eclairage, Vienna, 74 s.
3. Deliiski, N., 1991: Metod dla ocenki stepeni oblagoraživania bukovych pilomaterialov vo vremja ich proparki (*Approach for evaluation of the stage of enoblement of beech lumber during steaming*). In: Súčasné problémy a perspektívy sušenia bukového reziva. Zvolen. ES-VŠLD vo Zvolene, s. 37-44.
4. Deliiski, N., 2003: Modelirane i technologii za proparvane na drveny materiali v avtoklavi (Modeling and technologies for steaming wood materials in autoclaves). Dissertation for Dr.Sc., University of Forestry, Sofia, 358 s.
5. Deliiski, N.; Dzurenda, L., 2003: Avtomatičeskoe upravlenije procesom konvektivno-kamernoj suški bukovych pilomaterialov s sochraneniem ili c dopustimym izmenenijem ich estestvennoj okraski (Automatic control of the convective drying process of beech lumber in chambers preserving the natural colour of the wood). In: Annals of Warsaw Agricultural University – Forest and Wood Technology 53. s. 42-46.
6. Drahoš, V.; Viktorin, Z., 1975: Souhrn poznatku a výpočtových podkladu z výskumu sušení a sušáren řeziva.(Summary of knowledge and calculation basis from the research of the drying process and drying kilns). Praha. VÚD, p. 264.
7. Dzurenda, L., 1993: Energetická náročnosť sušenia reziva v malokapacitných komorových sušiarňach. (Energy consumption of drying of sawnwood in smallcapacity kilns). In Sušenie dreva v malovýrobe. Zvolen: DF-TUZVO, p. 97-111.
8. Dzurenda, L; Deliiski, N., 2000: Analysis of moisture content changes in beech wood sleepers in the steaming process with saturated water steam. Wood research. 45: (4) 1-7.
9. Dzurenda, L.; Deliiski, N., 2004: Energetic evaluation of the beech lumber drying regime without color changes of wood mass. In: Trieskové a beztrieskové obrábanie dreva.04´. Zvolen. Vydavateľstvo Technickej univerzity vo Zvolene, 331-337.
10. Dzurenda, L.; Deliiski, N., 2009: Matematický model výpočtu technicky zdôvodniteľnej normy spotreby tepla na sušenie reziva v komorovej sušiarni. (*Mathematical model for the calculation of the technical qualification norm of the heat energy consumption for drying of sawnwood in a drying chamber*). Acta facultatis xylologiae, 51(2): 49-62.
11. Dzurenda, L.; Deliiski, N., 2010: Tepelné procesy v technológiách spracovania dreva. (*Thermal processes in the wood processing technologies*). Zvolen, Vydavateľstvo Technickej univerzity vo Zvolene, p. 274.
12. Glijer, L, 1990: Zužycie energii w suzszarce cyklicznego dzialania do tarcicy. (*Use of the energy in the drying chambers*). Przemysl drewny 41 (12): 18-20.
13. Halaj, M., 1999: Vplyv hydrotermickej úpravy dreva na zmenu farby bukového dreva. (*Influence of the hydrothermal treatment on the change of colour of beech wood*). [Dizertačná práca DF - TU Zvolen, Zvolen, 74 p.
14. Kačík, F., 2001: Tvorba a chemické zloženie hydrolyzátov v systéme drevo-voda-teplo. (*Creation and chemical composition of hydrolysates in the system wood-water-heat*). Zvolen. Vydavateľstvo TU vo Zvolene. 75 p.
15. Klement, I.; Smilek, P., 2010: Vplyv teploty na proces vysokoteplotného sušenia bukového reziva. (*Temperature influence on the process of high temperature drying of beech lumber*). Acta facultatis xylologiae, 52 (2): 34-41.
16. Klement, I.; Balkovský, I.; Smilek, P. 2011: Vplyv teploty na proces kontaktného sušenia bukového reziva. (*Temperature influence on the process of contact drying of beech lumber*). Acta facultatis xylologiae, 53(1):13-19.
17. Kollmann, F., 1955: Technologie des Holzes und der Holzwerkstoffe. 2 vyd. Betrlin-Göttingen-Heidelberg Munchen, Speinger – Verlag 1955, 2 zv.
18. Laurova, M.; Mamonova, M.; Kučerova, 2004: Proces parciálnej hydrolýzy bukového dreva (*Fagus sylvatica* L.) parením a varením. (*Process of partial hydrolysis of beech wood (Fagus sylvatica L.) by steaming and cooking*). [Vedecké štúdie 2/2004/A], Zvolen, Vydavateľstvo TU vo Zvolene 2004.
19. Pervan, S., 2000: Priručnik za tehničko sušenie drva. Zagreb, Sand, 272 p.
20. Trebula, P., 1989: Hydrotermická úprava a ochrana dreva, časť: Hydrotermická úprava dreva. (Hydro-thermal treatment and protection of wood, part: Hydro-thermal treatment of wood). Zvolen, Vydavateľstvo Technickej unoiverzity vo Zvolene, 301 p.
21. Trebula, P.; Bučko, J., 1996: Vákuové sušnie dreva, technické, technologické a ekologické aspekty. (*Vacuum drying of wood, technical, technological and ecological aspects*). Vedecké štúdie 5/1996/B, Zvolen, Vydavateľstvo Technickej univerzity vo Zvolene, 70 p.
22. Trebula, P.; Klement, I., 2002: Sušenie a hydrotermická úprava dreva. (*Drying and hydro-thermal treatment of the wood*) Zvolen. Vydavateľstvo TU vo Zvolene. 449 p.
23. Videlov, Ch., 2003: Sušene i toplino obrabotvane na darvesinata. (*Drying and thermal processing of the wood*). Sofia, Izdatelska kšta pri LTU. 335 p.

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TEMATSKI PRILOZI

DRVO & NAMJEŠTAJ
STRUČNI ČASOPIS

Zoran Vlaović, Danijela Domljan, Ivica Grbac

Research of Temperature and Moisture during Sitting on Office Chairs

Istraživanje temperature i vlage pri sjedenju na uredskim radnim stolicama

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ABSTRACT • *When using an office chair, a person comes into direct contact with the seat, where the contact surface creates a microclimate that affects the person's positive or negative mood, depending on temperature and humidity. Relative to temperature and moisture, this microclimate may produce either a positive or a negative effect on a seated person. Foam based padding of seats and backrests have upholstery with insulating properties that prevent the escape of bodily heat and moisture. The present work, carried out with six subjects, was aimed at studying temperature and moisture as the contributing factors to sitting comfort during performance of usual tasks under controlled conditions. The study method employed temperature and moisture measurements on five different office chairs using the probes placed on or in the seats. The statistically evaluated results of objective measurements show significant differences in distribution of temperature and moisture among the tested seats and through different layers of padding materials and upholstery of individual seats. Generally, it may be concluded that the temperature on the seat surface is always higher than inside the seat. On the other hand, humidity is always lower on the seat surface. Temperature and moisture on the surface of moulded foam seats are higher than on other kinds of seats.*

Keywords: *office chair, seating, comfort, temperature, moisture, PU-foam, design, constructions.*

SAŽETAK • *Pri uporabi uredskoga radnog stolca korisnik dolazi u neposredan dodir sa sjedalom na čijoj se kontaktnoj površini stvara mikroklima koja utječe na čovjekovo pozitivno ili negativno raspoloženje, ovisno o temperaturi i vlazi. Sjedala i nasloni uredskih stolaca obloženi su materijalima prevučenim preko spužvastog ojastučenja koje ima izolirajuća svojstva, čime se sprječava odvođenje topline i vlage od tijela. U radu su istraživane temperatura i vlaga kao činitelji udobnosti sjedenja šest ispitanika na uredskim radnim stolcima za vrijeme obavljanja uobičajenih radnih zadataka u kontroliranim uvjetima. Istraživanje je provedeno metodom mjerenja temperature i vlage na pet različitih konstrukcija sjedala uredskih stolaca uz pomoć mjernih sondi ugrađenih na sjedalo ili u njega. Statistički obrađeni rezultati objektivnih mjerenja temperature i vlage pokazali su da postoje značajne razlike u distribuciji temperature i vlage kroz različite slojeve materijala i presvlaka između sjedala i unutar pojedinog sjedala. Opći je zaključak da je temperatura na površini sjedala uvijek viša od one u njegovoj unutrašnjosti, a vlaga je na površini sjedala uvijek niža od vlage u unutrašnjosti sjedala. Na sjedalu od hladno lijevane spužve temperatura i vlaga na njegovoj površini više su u usporedbi s drugim konstrukcijama sjedala.*

Ključne riječi: *uredski radni stolac, sjedenje, udobnost, temperatura, vlaga, PU spužva, konstrukcije*

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1 INTRODUCTION
1. UVOD

When sitting on an office chair, the body emits heat and moisture in the surrounding area and, depending on the body-seat contact area, these changes are higher or lower. Thermal comfort of a posture depends on the body and its environment, which is related to the size of a body surface available for temperature exchange (Raja and Nicol, 1997). Metabolism causes continuous radiation of heat and moisture. Consequently, perception of comfort depends on equilibrium between the receipt and release of heat and moisture at the contact point of the body and base (Hänel *et al*, 1997). As shown by Zacharkow (1988), the resistance to changes is highly related to the size of contact area and contact pressure. Accordingly, the feeling of comfort is connected with the parameters such as pressure, temperature and relative humidity at the contact point of the body and base (quote in: Hänel *et al*, 1997). According to Hänel *et al*. (1997) a mechanical component of comfort, the so called "mechanical comfort" is defined as a part of the overall comfort, which depends on distribution of a contact pressure on human body in the seat contact area. The value of contact pressure, its distribution and duration of action are the main factors of "mechanical comfort". Due to scarcity of research into office chairs, the examples from automotive industry can be used to show that thermal comfort is an important factor in ergonomic evaluation of car seats. Upholstery is one of the key factors that determine thermal comfort. Amongst other properties, upholstery must be airy and ensure transport of moisture (Cengiz and Babalık, 2009). Usually foam padding of a seat and a backrest of office chairs is covered by upholstery with insulating properties, which prevents the escape of heat from the body (Bartels 2003). Study results of Nicholson *et al*. (1999) show to what extent foam inhibits the transfer of heat, and that upholstery limits moisture evaporation. The resistance of invisible (latent) heat loss through upholstery also limits heat transfer. Foam padding impedes transfer of moisture from skin surface, too. The study by Diebschlag (1988) shows that permeability of foam depends not only on its composition but also on pressure. This suggests that thermal comfort varies for different people who use the same task chair, relevant to where and how long they exert pressure on the foam padding of seats and backrests (quotation in: Stumpf *et al*, 2002). In their study of different padding materials for wheelchairs, Fisher et al. (1978) found significant increase in the skin temperature under thighs and sitting bones of test subjects using 10 cm thick foam rubber pads (quotation in: Stumpf *et al*, 2002).

Different standards specify the requirements in thermal comfort (e.g. ISO 7730). However, the responses to indoor thermal environment can vary due to non-environmental factors such as different clothing, the difference in the level of activity, individual preferences to temperature and others. Studies have shown that indoor thermal conditions may affect the complaints, distraction and employee productivity. When using an office chair, a person comes into direct contact with a seat, on which the contact area creates a microclimate that affects the person's positive or negative mood, depending on temperature and humidity (Grbac, 1988). Some scientists investigated the effects under laboratory conditions: Pepler and Warner (1968) examined 36 male and 36 female students in an air-conditioned room and found out that at 26.7 °C they required more time to complete a task than at 20 °C, although lower prevalence of errors was at 26.7 °C; Fang *et al*. (2002) investigated the influence of several combinations of temperature and relative humidity on performance of simulated office tasks in 30 female subjects exposed to different combinations of temperature and relative humidity over approximately five hours. The results showed that there was no significant difference in performance of the tasks at higher and lower temperature/humidity combinations (quotation in: Hedge *et al*, 2005).

Human body maintains the temperature from 36 to 37 °C. Due to constant evaporation of moisture, the temperature on the body surface is around 34 °C (Brezigar, 1984, quotation in: Grbac, 1988). Our body continually delivers its heat to the environment. If delivery and conduction are too fast, one feels cold, but if it is too slow or if there is no exchange at all, one is hot. Upholstered products have thermal insulation, which is crucial for our life. This insulation depends on fabrics and other materials built into a product. Moisture absorption and heat conduction are interrelated and interdependent: a dry material is a better insulator than a wet one, and moisture absorption is better and faster at higher temperatures. The same is with the delivery of moisture – at higher temperature it is faster and its volume is bigger. Fabrics are better heat conductor than air, whereas air is a good insulator if trapped between two layers of upholstery (Grbac and Dalbelo-Bašić, 1996). In the view of the fact that office chairs are used for almost eight hours a day, it is important that they be constructed with the materials with very high moisture-absorbing and moisture-delivering capacity, relevant to perspiration of a seated person. Under normal conditions during one hour a person perspires 15-32 g of sweat per body square meter, whereas at the increased ambient temperatures or during the increased physical strain perspiration exceeds 100 g/m^2 (Grbac, 2006; Grbac and Domljan, 2007).

To date researches have shown that the maximum thermal comfort is achieved at the mean skin temperature of around 33.5 °C (Arens *et al*, 2006; Sakoi *et al*, 2007). In the study of Cengiz and Babalık (2009) it has been confirmed that upholstery in cars influenced thermal comfort and that the mean skin temperature ranged between 33.31 and 35.89 °C. Moreover, the area around the waist was found to be the most important one in determining perception of thermal comfort, whereas local thermal discomfort was particularly high on the back (Sakoi *et al*, 2007).

Measurements of physical properties of upholstering (e.g. determination of water vapour permeability) show that at the beginning permeability increases with

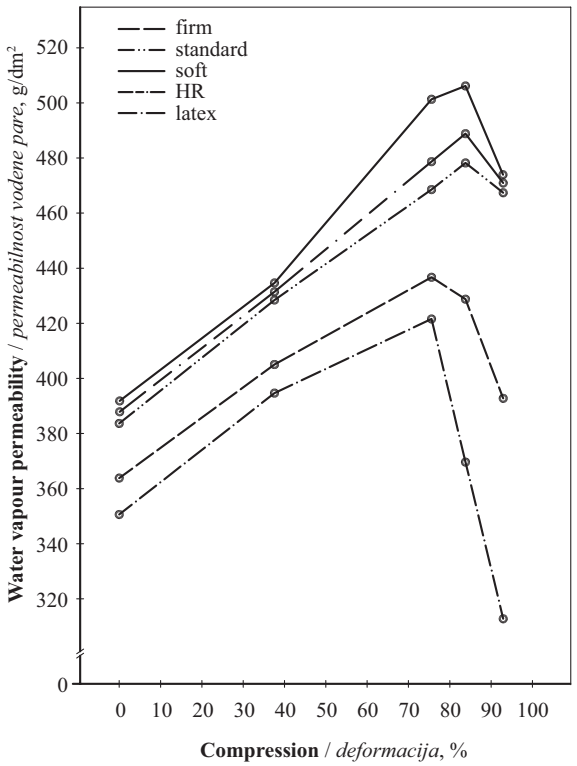


Figure 1 Permeability for humidity of different PU-foams vs. relative compression (source: Kurz *et al*, 1989)
Slika 1. Permeabilnost vlage različitih PU spužvi u odnosu prema relativnoj deformaciji (izvor: Kurz i sur., 1989)

increased compressing of the upholstering, due to smaller diffusion distance. Only after compression of 75-85 % of the original thickness, due to its increasing density, water vapour permeability is reduced (Figure 1) (Kurz *et al*, 1989). This interdependence points out how important it is that seats and backrests are permeable to water vapour in order to allow escape (evaporation) of moisture from upholstering materials.

Ick *et al*. (1976) studied the use of flexible PU-foams in car seats and showed that heat conductivity of PU-foams ranged between 0.04 and 0.05 W/m·K (at 15 % compression), which depended on the cellular foam cell structure. Estimates of heat produced during drive show that minimal conductivity of 50 mm and 100 mm padding should be 0.11 W/m·K and 0.21 W/m·K, respectively, whereas the aimed dissipation of sufficient heat must be vertical through the padding material. If this is not possible, the temperature in a seat goes up to 37°C and perspiration is very high. If the evaporated water is not released sufficiently fast, it condenses on the sitting area and this is a definitely unwelcome and unpleasant effect. Practical tests and subjects' opinion show that with PU upholstering sufficient volume of water vapour and heat are transferred horizontally (instead of vertically) from the sitting area, which ensures maintenance of comfortable sitting climate. The volume of this horizontal transport of moisture is mainly determined by the composition of users' clothes and quality of seats' upholstery. In addition, changing of sitting posture provides additional air cooling.

Ideal humidity at the skin-surface contact point is 40-65 % RH. Contact temperature should not change for more than several degrees (Cochran and Palmieri, 1980; quotation in: Nicholson *et al*, 1999). Clinical estimates show that relative humidity measured under the thighs during sitting is between 40 % and 100 % RH, and that the temperature under sitting bones varies between 30 °C and the body temperature. Heat flow from the skin varies during posture change from -9 to +106 W/m^2. When it comes to car seats or beds, for enjoying comfort under hot microclimate conditions, it is necessary to ensure sufficient moisture drain capacity from the contact point. Hänel *et al*. (1997) showed that thermal behaviour of an upholstered chair depends mainly on thermal properties of the upper layer, i.e. the one that is in contact with the body. Constructional variations of the supporting part of a seat did not present any significant improvement. In his research of quality and comfort of lying, Grbac (1988) obtained much the same results related to the importance of the upper layer for human health and for providing sitting and laying comfort.

Figure 2 shows resistance of two different fabrics and of a plastic sheet not permeable to moisture transfer. As is the case with temperature, it can be concluded about moisture, too, that the top layer is most important for the feeling of comfort (Hänel *et al*. 1997; Qian and Fan, 2006). According to Bartels (2003), for physiological comfort of a chair, thermal insulation is usually less important than moisture transfer. Good moisture absorbents are natural fibres, coconut fibres, wool and cotton. On the other hand, synthetic materials such as polyesters, polypropylene, PU-foam and polyamide are poor moisture absorbents (Grbac and Ivelić, 2005; Vlaović *et al*, 2006). Grbac and Dalbelo-Bašić (1996) have confirmed that the materials used to produce a decorative and upper layer of mattresses are crucial for sleeping thermophysiology but natural construction materials should be given the preference.

The aim of this study was to detect the flow passage of heat and moisture that passes from a seat surface to its interior through upholstery and PU-foam of different characteristics during the sitting of users, i.e. to determine the conductivity of these materials. The goal was to determine the capability of the equipment for determination of thermophysiological characteristics of sitting by temperature and humidity measurements, and to detect occurrence of heat and moisture on the seat surface and interior during sitting.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The research method applied temperature and humidity measurements with the probes supplied with two corresponding sensors in one housing (Figure 3a). Data were collected by electronic device *HOBO® Weather Station H21-001* (Onset Computer Corporation, USA) and data processing was performed with *HOBOware Pro ver. 2.7.3.* and SPSS ver. 13.0 software.

The probes were positioned in two ways (Vlaović, 2009): into the seats and on the surface, just above the "interior" probes, and then fixed with the adhesive (Figures 3b and 3c).

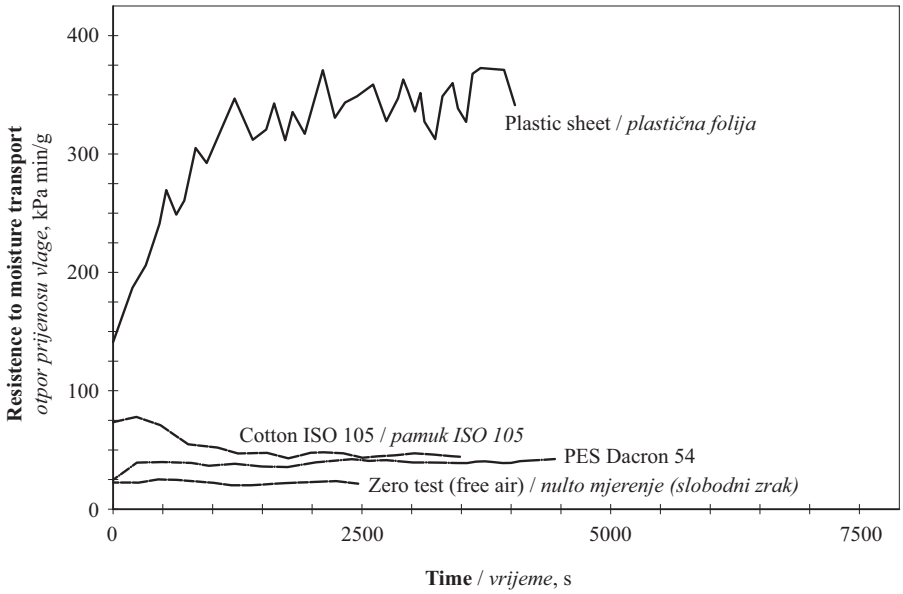


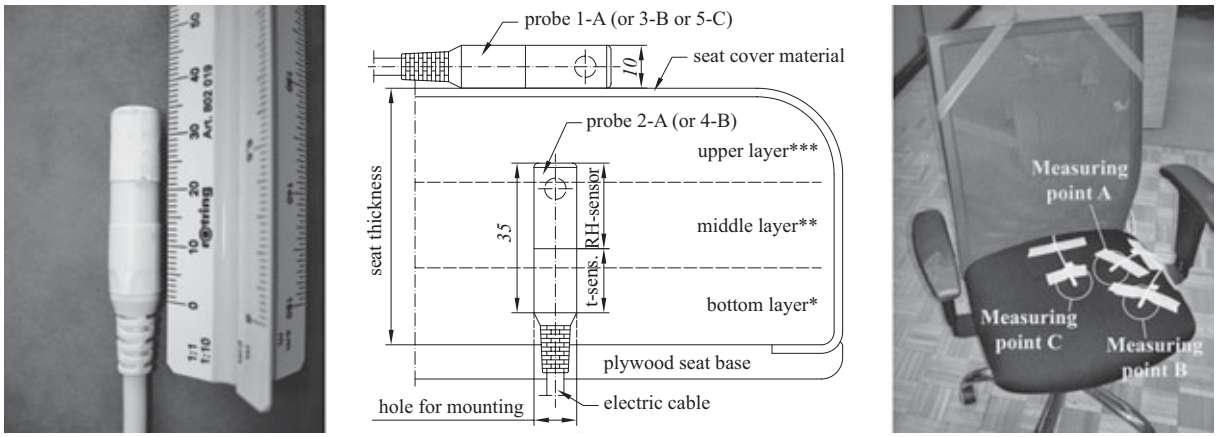
Figure 2 Resistance to moisture transport measured with the IFP indenter (source: Hänel i sur. 1997)
Slika 2. Otpor prijenosu vlage mjeren uz pomoć IFP indentora (izvor: Hänel i sur., 1997)

There were six probes in total (three on the seat, two in the seat and one in the room), placed at four measurement points (A, B, C and D):

– Measuring point A covered the area under the gluteus (buttocks) around the sitting bone of the left lower extremity on the seat surface (probe 1-A) and in the seat (probe 2-A);
– Measuring point B covered the area under the left thigh on the seat surface (probe 3-B) and in the seat (probe 4-B);
– Measuring point C covered the area between the lower extremities in the centre of the seat surface (probe 5-C);
– Measuring point D covered the area behind the backrest (probe 6-D) to monitor room conditions.

Due to sitting and compression of the PU-foam, the probes in the seats were partially pushed out. On the underside of the seats the probes had been fixed with the adhesive, which also closed the holes with the probes, thus preventing the escape/entry of moisture and heat. Given the size and position of the built in probes, we can say that temperature and moisture were measured in the central and lower layer of the seat upholstering.

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. In order to minimize the influence of clothing, the subjects were wearing cotton underwear and light linen or cotton clothing. According to the pre-determined schedule, six subjects were tested on five selected chairs, using two chairs per day, each during 90 minutes. Minimal suspension time between two measurements was 10 minutes. Sampling frequency was one per minute. Every sample contained the information on temperature and relative humidity (6 of each). Prior to the measurement, the height of the seats and armrests had been tuned to every subject in order to ensure maximum comfort, all in accordance with the table height, as required by the corresponding basic ergonomic criteria.



a) The probe / *Mjerna sonda*
b) Probes installation on/in the unloaded seat / *Shematski prikaz ugradnje sonde na/u neopterećeno sjedalo*
c) Probes on the seat / *Sonde postavljene na sjedalo*

Figure 3 Measurement probe (S-THB-M008) and installation
Slika 3. Mjerna sonda (S-THB-M008) i način njezine ugradnje

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

Table 1 Seat characteristics of office chair models
Tablica 1. Svojstva sjedala modela uredskih stolica

Model	**M1**	**M2**	**M3**	**M4**	**M5**
Seat characteristic *značajka sjedala*	A notch for coccyx and prostate, PU 2-layer *urez za trticu i prostatu, dvoslojni PU*	PU 3-layer *troslojni PU*	More suited to female, mobile in 3D, PU 2-layer *prikladnije za žene, gibljivo u 3D, dvoslojno*	Mobile in all directions (3D), PU 1-layer *gibljivo u svim smjerovima (3D), jednoslojno*	Standard, PU 1-layer *standardno, jednoslojni PU*
Cover material composition *sastav presvlake*	100% Polyester	100% Polyester	100% Polyester	100% Polyester (Trevira® CS)	100% Polyester
Seat construction *konstrukcija sjedala*	Slabstock foams *rezane spužve*: 40 mm PT3246*** 20 mm PG65120*	Slabstock foams *rezane spužve*: 20 mm VISCO*** 20 mm PT3246** 20 mm PG65120*	Moulded PU-foam *hladno lijevana spužva*: 10 mm PU 4040 *** 45 mm pocket springs *džepićaste opruge** (D45 mm / r1.8 mm)	Moulded 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
Seat thickness *debljina sjedala*	60 mm	60 mm	55 mm	55 mm	60 mm

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

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 constructions that enable proper and comfortable sitting posture as a pre-condition for comfort (Vlaović *et al*, 2008, Vlaović *et al*, 2010). In addition, the attention was paid to compliance of the samples with the current standards regarding functional dimensions. Every sample is detailed in Table 1. All seats were made of non-hygroscopic material.

2.2 Subjects
2.2. Ispitanici

The study included healthy females and males (3 of each). The subjects' details are given in the following table:

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
Arithmetical mean *aritmetička sredina*	35	173.8	72.33	23.90
Standard deviation *standardna devijacija*	4.28	8.57	9.99	2.40

* Body Mass Index / *indeks tjelesne mase*

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Measurement results for temperature and moisture on/in the studied seats are given as arithmetic means and standard deviations in Table 3. It is clear that the probe 3-B of the M4 model recorded the highest temperature (t_{max}=35.31 °C), and the probe 2-A of the M5 model the lowest temperature (t_{min}=24.82 °C). The highest moisture was recorded by the probe 2-A of the M4 model (RH_{max}=71.88 %), and the lowest by the probe 3-B of the M2 model (RH_{min}=47.43 %).

The analysis of temperature measurements obtained from the probes in the seats (2-A and 4-B) vs. their surface pairs (1-A and 3-B) shows that the seat surface temperature is always higher than the interior temperature of the corresponding seat. In such a temperature gradient, the biggest differences are recorded in the M5 model (gluteal area Δ=9.55 °C; thigh area Δ=9.48 °C), and the smallest in the M1 model (gluteal area Δ=8.80 °C; thigh area Δ=8.53 °C). In other words, the M1 model has better vertical permeability of heat, which should ensure more comfortable sitting because the temperature does not stay only on the surface. With regard to previous findings on the "interior" temperatures, it can be assumed that the M1 seat is a minor thermal insulator and that, under specific ambient conditions, sitting on that chair will be more comfortable.

The analysis of moisture measurements obtained from the probes in the seats (2-A and 4-B) vs. their surface pairs (1-A and 3-B) shows that the seat interior moisture content is always higher than the surface moisture of the corresponding seat. In such a moisture gradient the biggest differences are recorded in the M5 model (gluteal area Δ=15.96 %; thigh area Δ=16.58 %), and the smallest in the M1 model (gluteal area Δ=11.25 %; thigh area Δ=12.56 %). In other words, the M1 model has better vertical permeability, which should provide more comfort.

Along with the previously described analyses, the obtained results were also compared with the use of the Student's *t*-test for dependent samples. The recorded temperatures and moisture contents were compared separately as well as their occurrence on the seat surface and interior. Only significant differences are shown (Tables 4 and 5).

The results and their analysis show that (I.) statistically (Table 4) in the gluteal area on the M4 model seat surface, the temperature is significantly higher than on the models M3 (t= -3.98; p=0.011) and M5 (t=2.24; p=0.075). Inside the M1 seat model, the temperature is significantly higher than in the models M2 (t=2.55; p=0.051), M3 (t=2.70; p=0.043) and M5 (t=6.12; p=0.002), whereas statistically in the M4 seat model, it is significantly higher than in the M3 model (t= -3.50; p=0.017). (II.) Statistically, in the area of thighs on the surface of the M4 seat model, the temperature is significantly higher than on the seat models M2 (t= -2.52; p=0.054), M3 (t= -4.19; p=0.009) and M5 (t=2.65; p=0.046). Inside the seats the temperature is significantly higher in the M1 model than in the models M2 (t=3.30; p=0.021) and M5 (t=5.14; p=0.004), and statistically the inside seat temperature of the M4 model is significantly higher than in the M3 model (t= -2.14; p=0.085). (III.) The temperature measurements between lower extremities on the M1 model are significantly lower than on the models M2 (t= -4.30; p=0.008), M3 (t= -5.92; p=0.002), M4 (t= -5.41; p=0.003) and M5 (t= -5.20; p=0.003). This finding is not a surprise with respect to the seat construction of the M1 model, which had a probe slot. However, the temperature on the same place on the M4 seat is significantly higher than on the seat models M2 (t= -2.17; p=0.082), M3 (t= -4.16; p=0.009) and M5 (t=2.43; p=0.060).

Moisture content (Table 5) (I.) in the gluteal area on the M4 model seat surface is significantly higher than on the seat models M1 (t= -4.32; p=0.008), M2 (t= -2.73; p=0.041), M3 (t= -4.91; p=0.004) and M5 (t=2.23; p=0.077). Relative humidity inside the seat model M4 is significantly higher than in the seats of M1 (t= -2.70; p=0.043) and M3 (t= -2.75; p=0.041). (II.) Moisture measured in the area of thighs on the seat surface of the M4 model is significantly higher than on the models M1 (t= -7.59; p=0.001), M2 (t= -2.89; p=0.034) and M3 (t=

Table 3 Arithmetical mean (and standard deviations) of measured temperature and humidity on/in the seat
Tablica 3. Aritmetičke sredine (i standardne devijacije) izmjerene temperature i vlage u/na sjedalu

Sample *Uzorak*	**Probe 1-A** *Sonda 1-A*		**Probe 2-A** *Sonda 2-A*		**Probe 3-B** *Sonda 3-B*		**Probe 4-B** *Sonda 4-B*		**Probe 5-C** *Sonda 5-C*	
	t, °C	*RH*, %	*t*, °C	*RH*, %	*t*, °C	*RH*, %	*t*, °C	*RH*, %	*t*, °C	*RH*, %
M1	34.52 (0.75)	53.01 (6.09)	25.72 (0.26)	64.26 (4.49)	34.42 (1.32)	48.06 (3.66)	25.89 (0.43)	60.62 (3.79)	33.50 (0.71)	55.30 (8.90)
M2	34.34 (0.80)	50.99 (5.77)	25.21 (0.38)	64.20 (5.79)	34.27 (0.98)	47.43 (4.40)	25.28 (0.40)	61.99 (5.00)	34.36 (0.52)	62.34 (12.33)
M3	33.93 (0.69)	50.22 (3.57)	24.85 (0.81)	65.24 (3.34)	34.46 (0.50)	47.80 (3.88)	25.14 (0.81)	61.66 (2.57)	34.23 (0.52)	57.18 (5.61)
M4	34.98 (0.26)	58.52 (5.54)	25.58 (0.52)	71.88 (4.38)	35.31 (0.27)	51.96 (4.31)	25.76 (0.39)	66.93 (1.57)	35.03 (0.50)	68.10 (6.87)
M5	34.37 (0.48)	51.86 (4.96)	24.82 (0.48)	67.82 (5.00)	34.49 (0.72)	49.44 (4.66)	25.01 (0.60)	66.02 (5.53)	34.51 (0.41)	65.79 (6.21)

Note: Probe1-A: temperature and moisture under the gluteus on the seat; Probe 2-A: temperature and moisture in the seat under 1-A; Probe 3-B: temperature and moisture under the thigh on the seat; Probe 4-B: temperature and moisture in the seat under 3-B; Probe 5-C: temperature and moisture in the centre of the seat between the lower extremities. / *Napomena: Sonda 1-A: temperatura i vlaga ispod gluteusa na sjedalu; sonda 2-A: temperatura i vlaga u sjedalu ispod 1-A; sonda 3-B: temperatura i vlaga ispod natkoljenice na sjedalu; sonda 4-B: temperatura i vlaga u sjedalu ispod 3-B; sonda 5-C: temperatura i vlaga na sredini sjedala između nogu ispitanika.*

Table 4 Results of *t*-test for paired samples for temperature
Tablica 4. *T*-test za zavisne uzorke rezultata temperature

Probe sonda 1-A	Mean °C	*SEM*	*SD*	*t*-test	*p* value
M3	33.93	0.282	0.690	-3.977	0.011*
M4	34.98	0.104	0.256		
M4	34.98	0.104	0.256	2.244	0.075**
M5	34.37	0.196	0.481		
2-A	Mean	*SEM*	*SD*	*t*-test	*p* value
M1	25.72	0.106	0.261	2.550	.051**
M2	25.21	0.155	0.380		
M1	25.72	0.106	0.261	2.701	.043*
M3	24.85	0.330	0.808		
M1	25.72	0.106	0.261	6.123	.002*
M5	24.82	0.196	0.480		
M3	24.85	0.330	0.808	-3.498	.017*
M4	25.58	0.211	0.517		
3-B	Mean	*SEM*	*SD*	*t*-test	*p* value
M2	34.27	0.401	0.982	-2.515	.054**
M4	35.31	0.111	0.273		
M3	34.46	0.205	0.503	-4.187	.009*
M4	35.31	0.111	0.273		
M4	35.31	0.111	0.273	2.646	.046*
M5	34.49	0.295	0.722		
4-B	Mean	*SEM*	*SD*	*t*-test	*p* value
M1	25.89	0.175	0.429	3.301	.021*
M2	25.28	0.162	0.396		
M1	25.89	0.175	0.429	5.144	.004*
M5	25.01	0.246	0.604		
M3	25.14	0.330	0.809	-2.144	.085**
M4	25.76	0.161	0.394		
5-C	Mean	*SEM*	*SD*	*t*-test	*p* value
M1	33.50	0.289	0.707	-4.298	.008*
M2	34.36	0.211	0.516		
M1	33.50	0.289	0.707	-5.915	.002*
M3	34.23	0.213	0.521		
M1	33.50	0.289	0.707	-5.411	.003*
M4	35.03	0.205	0.501		
M1	33.50	0.289	0.707	-5.202	.003*
M5	34.51	0.165	0.405		
M2	34.36	0.211	0.516	-2.170	.082**
M4	35.03	0.205	0.501		
M3	34.23	0.213	0.521	-4.159	.009*
M4	35.03	0.205	0.501		
M4	35.03	0.205	0.501	2.426	.060**
M5	34.51	0.165	0.405		

Table 5 Results of t-test for paired samples for moisture
Tablica 5. T-test za zavisne uzorke rezultata vlage

Probe sonda 1-A	Mean %	*SEM*	*SD*	*t*-test	*p* value
M1	53.01	2.487	6.091	-4.324	.008*
M4	58.52	2.263	5.543		
M2	50.99	2.355	5.768	-2.730	.041*
M4	58.52	2.263	5.543		
M3	50.22	1.457	3.570	-4.909	.004*
M4	58.52	2.263	5.543		
M4	58.52	2.263	5.543	2.226	.077**
M5	51.86	2.026	4.962		
2-A	Mean	*SEM*	*SD*	*t*-test	*p* value
M1	64.26	1.833	4.489	-2.700	.043*
M4	71.88	1.789	4.381		
M3	65.24	1.362	3.336	-2.745	.041*
M4	71.88	1.789	4.381		
3-B	Mean	*SEM*	*SD*	*t*-test	*p* value
M1	48.06	1.496	3.664	-7.588	.001*
M4	51.96	1.761	4.314		
M2	47.43	1.796	4.399	-2.886	.034*
M4	51.96	1.761	4.314		
M3	47.80	1.583	3.878	-3.428	.019*
M4	51.96	1.761	4.314		
4-B	Mean	*SEM*	*SD*	*t*-test	*p* value
M1	60.62	1.546	3.788	-4.794	.005*
M4	66.93	0.642	1.574		
M2	61.99	2.041	5.000	-2.204	.079**
M4	66.93	0.642	1.574		
M3	61.66	1.050	2.572	-5.370	.003*
M4	66.93	0.642	1.574		
5-C	Mean	*SEM*	*SD*	*t*-test	*p* value
M1	55.30	3.634	8.902	-3.376	.020*
M4	68.10	2.804	6.869		
M1	55.30	3.634	8.902	-7.211	.001*
M5	65.79	2.537	6.215		
M3	57.18	2.292	5.614	-4.295	.008*
M4	68.10	2.804	6.869		
M3	57.18	2.292	5.614	-4.256	.008*
M5	65.79	2.537	6.215		

Mean – arithmetical mean / *aritmetička sredina; SEM* – standard error of arithmetic mean / *standardna pogreška aritmetičke sredine; SD* – standard deviation / *standardna devijacija;* * significant difference of 5 % / *razlika značajna na razini od 5 %;* ** significant difference of 10 % / *razlika značajna na razini od 10 %; p* – difference significance / *značajnost razlike*
Note / *Napomena*: Since the experiment included only 6 subjects, a milder significance criterion was applied i.e. $p<0.10$. / *S obzirom na to da je u eksperimentu sudjelovalo samo šest ispitanika, uveden je nešto blaži kriterij značajnosti, tj. p<0,10.*

-3.43; p=0.019). Inside the M4 model seat, moisture content is significantly higher than in the seat of the M1 (t= -4.79; p=0.005), M2 (t= -2.20; p=0.079) and M3 (t= -5.37; p=0.003). (III.) Moisture content between the lower extremities in the model M4 is significantly higher than in the models M1 (t= -3.38; p=0.020) and M3 (t= -4.30; p=0.008), and in the model M5 where it is significantly higher than in the seats of M1 (t= -7.21; p=0,001) and M3 (t= -4.26; p=0.008).

4 CONCLUSION
4. ZAKLJUČAK

Based on the study with six subjects and on the study results, the following may be concluded:

Surface temperature of a seat is always higher than its interior temperature. In this respect, the models with notched seats show smallest differences, which may lead to the conclusion that such seats are the smallest thermal insulators and, therefore, provide more

comfortable sitting. A notch is relatively close to the observed areas and presumably provides better cooling of the padding materials.

Surface moisture on a seat is always lower than that inside the seat. Again, the least differences occur with the notched seats. In other words, notched seats have better vertical permeability and provide more comfort.

On the seat surface of the chairs with moulded PU-foam, the temperatures are higher than on other chairs. The same is with moisture, which develops on the body-seat contact area. It is interesting to note that the seat, herewith referred to, is upholstered with *Trevira® CS* fabrics with some distinctive properties that may influence the feeling of warmth and humidity during sitting.

On a notched seat, the temperature between the lower extremities is below that on all other seat models.

From thermophysiological standpoint of seat comfort, the ideal seat may be a notched one. The least comfortable is that constructed of moulded PU-foam because of its closed structure, which prevents rapid air exchange from the inside of the material.

Measurements during the experiment have shown that the present equipment can determinate differences between temperatures and moisture. For moisture measurement it would be better if probes were smaller in order to achieve accurate measurements throughout the seat cross section. In other words, the problem was in probes size considering seat thickness.

We suggest further research into temperature and humidity of upholstery with different characteristics and composition of raw materials, different quality and properties of PU-foam upholstering and, definitely, with more subjects and samples.

5 REFERENCES
5. LITERATURA

1. Arens, E.; Zhang, H.; Huizenga, C., 2006: Partial- and whole-body thermal sensation and comfort – Part I: Uniform environmental conditions. Journal of Thermal Biology 31: 53-59 http://dx.doi.org/10.1016/j.jtherbio.2005.11.028.
2. Bartels, V.T., 2003: Thermal comfort of aeroplane seats: influence of different seat materials and the use of laboratory test methods, technical note. Applied Ergonomics 34: 393-399 http://dx.doi.org/10.1016/S0003-6870(03)00058-9.
3. Cengiz, T.G.; Babalık, F.C., 2009: The effects of ramie blended car seat covers on thermal comfort during road trials. International Journal of Industrial Ergonomics 39: 287-294 http://dx.doi.org/10.1016/j.ergon.2008.12.002.
4. Grbac, I., 1988: Istraživanje kvalitete ležaja i poboljšanje njegove konstrukcije – disertacija. Sveučilište u Zagrebu, Šumarski fakultet, Zagreb.
5. Grbac, I.; Dalbelo Bašić, B., 1994: Thermal conductivity and moisture permeability in mattress. Drvna ind. 45 (4): 130-134.
6. Grbac, I.; Dalbelo-Bašić, B., 1996: Comparison of thermo-physiological properties of different mattress structures. Proceedings of the 18th international conference on Information technology interfaces, Pula, Croatia, June 18-21. University of Zagreb, University Computing Centre Zagreb, pp. 113-118.
7. Grbac, I.; Ivelić, Ž., 2005: Ojastučeni namještaj, Sveučilište u Zagrebu, Šumarski fakultet, Zagreb.
8. Grbac, I., 2006: Krevet i zdravlje. Sveučilište u Zagrebu, Šumarski fakultet, Zagreb.
9. Grbac, I.; Domljan, D., 2007: Namještaj i zdrav život, Sigurnost 49(3): 263-279.
10. Hänel, S.-E.; Dartman, T.; Shishoo, R., 1997: Measuring methods for comfort rating of seats and beds. International journal of Industrial Ergonomics 20: 163-172 http://dx.doi.org/10.1016/S0169-8141(96)00049-2.
11. Hedge, A.; Sakr, W.; Agarwal, A., 2005: Thermal effects on office productivity. Proceedings of the Human factors and ergonomics society 49th Annual meeting, pp. 823-827.
12. Ick, J.; Rothermel, H.M.; Hauptmann, H.G., 1976: The Application of Flexible Polyurethane Foam for Automotive Seating. Journal of Cellular Plastics 12: 177-181 http://dx.doi.org/10.1177/0021955X7601200307.
13. Kurz, B.; Diebschlag, W.; Heidinger, F., 1989: Recommendation for ergonomic and climatic physiological vehicle seat design. Journal of Cellular Plastics 25: 125-137 http://dx.doi.org/10.1177/0021955X8902500203.
14. Nicholson, G.P.; Scales, J.T.; Clark, R.P.; de Calcina-Goff, M.L., 1999: A method for determining the heat transfer and water vapour permeability of patient support systems. Medical Engineering & Physics 21: 701-712 http://dx.doi.org/10.1016/S1350-4533(00)00003-5.
15. Qian, X.; Fan, J., 2006: Interactions of the surface heat and moisture transfer from the human body under varying climatic conditions and walking speeds. Applied Ergonomics 37: 685-693 http://dx.doi.org/10.1016/j.apergo.2006.01.002.
16. Raja, I.A.; Nicol, F., 1997: A technique for recording and analysis of postural changes associated with thermal comfort. Applied Ergonomics 28 (3): 221-225 http://dx.doi.org/10.1016/S0003-6870(96)00036-1.
17. Sakoi, T.; Tsuzuki, K.; Kato, S.; Ooka, R.; Song, D.; Zhu, S., 2007: Thermal comfort, skin temperature distribution, and sensible heat loss distribution in the sitting posture in various asymmetric radiant fields. Building and Environment 42(12): 3984-3999 http://dx.doi.org/10.1016/j.buildenv.2006.10.050.
18. Stumpf, B.; Chadwick, D.; Dowell, B., 2002: The Attributes of Thermal Comfort, Ergonomic criteria for the design of the Aeron® chair, Herman Miller Inc., U.S.A., www.hermanmiller.com
19. Vlaović, Z.; Konjuh, J.; Domljan, D., 2006: A study into the quality of the mattress cover fabrics. Proceedings of 16th international scientific conference: European Union – Challenges and perspectives for wood-processing industry, Zagreb, Croatia, October 14th 2006. Innovawood, UFI-Paris, University of Zagreb, Faculty of Forestry, pp. 101-106.
20. Vlaović, Z.; Bogner, A.; Grbac, I., 2008: Comfort Evaluation as the Example of Anthropotechnical Furniture Design. Coll. Antropol. 32(1): 277-283.
21. Vlaović, Z., 2009: Comfort factors of office chairs (Doctoral thesis, in Croatian). University of Zagreb, Faculty of Forestry, Zagreb.
22. Vlaović, Z.; Grbac, I.; Domljan, D.; Bublić, A., 2010: Office work chairs – research of deformations and comfort index (In Croatian). Drvna ind. 61(3): 159-168.

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Adaptability of Kitchen Furniture for Elderly People in Terms of Safety

Sigurnosna prilagođenost kuhinjskog namještaja starijim osobama

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ABSTRACT • *The number of senior citizens is rapidly increasing, which consequently signifies an increase in the number of people having sight, hearing or memory difficulties, people with hampered mobility, and people who find it increasingly difficult to process information. Elderly persons experience a greater degree of risk whilst performing daily tasks in their kitchens. Moreover, they are more susceptible to infection and illnesses, necessitating greater care to achieve hygienic conditions within their kitchens. The goal of our research was to determine whether people are generally content with the functionality of their kitchens and whether the degree of dissatisfaction increases with the age of the users. The study aims to pinpoint any major problems facing elderly people whilst working in their kitchens and to establish criteria for kitchen furniture design that could be tailored to senior users' interests, with the focus on safety. This research was carried out via individual surveys at the respondents' homes. 204 respondents participated in the research. The results show that most users do not realize that, with more appropriate kitchen equipment, they could perform daily tasks faster, safer, and with less effort. Common shortcomings include insufficient lighting (32 %), inappropriate sequential composition of work surfaces (56 %), ease of hygiene maintenance (68 %), inappropriately - shaped furniture (72 %), and tasks that become troublesome because of declining memory (75 %). We believe that it is necessary to design kitchen equipment specifically adjusted for the needs of the elderly.*

Key words: *kitchen, elderly, senior, equipment, design, safety, ergonomics*

SAŽETAK • *Udjel starijih osoba u stanovništvu u enormnom je porastu, slijedom čega se povećava broj ljudi koji imaju slabiji vid, sluh, memoriju, fizičke probleme i probleme s percipiranjem informacija. Stariji su zbog toga osjetljiviji na ozljede, koje mogu nastati pri obavljanju svakodnevnih poslova u kuhinji. Osim toga, za njihovu je sigurnost važno voditi brigu o higijenskim standardima jer su osjetljiviji na infekcije i bolesti. Cilj ovog istraživanja bio je utvrditi jesu li ljudi zadovoljni funkcionalnošću njihove kuhinje i osjećaju li se sigurno te raste li nezadovoljstvo kuhinjom sa starošću korisnika. Željeli smo identificirati probleme s kojima se pri radu u kuhinji suočavaju stariji ljudi i utvrditi kriterije za izradu kuhinjskog namještaja prilagođenoga starijim ljudima u smislu sigurnosti. Istraživanje je provedeno putem osobnih intervjua u domu ispitanika. U istraživanju su sudjelovala 204*

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ispitanika. Rezultati istraživanja pokazuju kako ljudi ne znaju da bi uz prikladniju opremu brže, lakše i sigurnije mogli obavljati svakodnevne zadatke. Starije osobe u kuhinji prije svega imaju probleme s održavanjem higijene – 68 %, s neodgovarajućim rasporedom kuhinjskih centara – 56 %, s neadekvatnom rasvjetom – 32 %, s nepropisno dizajniranim namještajem – 72 %, s problemima slabijeg pamćenja – 75 %. Vjerujemo da je potrebno projektirati kuhinjski namještaj prilagođen specifičnim zahtjevima starijih osoba.

Ključne riječi: *kuhinja, starije osobe, oprema, dizajn, sigurnost, ergonomija*

1 INTRODUCTION
1. UVOD

Owing to an increasingly higher standard of living as well as improvements in health care, the proportion of senior citizens in the general population is rapidly increasing. Statistical prognosis indicates that, by 2030, 36 % of people will be over the age of 60 (Hilderbrand, 2002). Information from the Statistical Office of the Republic of Slovenia states that, in 2010, the percentage of Slovenian citizens over 60 years of age was 21.97 %, out of which 58.21 % were female (Statistic Office RS, 2010). There had also been an increase in the number of citizens with sight issues, hampered movement capabilities, and degrees of memory loss. In Slovenia dementia is encountered in over 25,000 people and the number is ever-increasing. Among citizens older than 85 years, almost half suffer from dementia and every tenth person suffering from it is younger than 50. Over the next 20 years, the number of people suffering from dementia is likely to double.

In 2004 researchers from the University of Sheffield, School of Architecture carried out the research into the influence of architecture on the quality of life. They were chiefly interested in how appropriate the common living quarters were, for the research focused on the suitability of the design of retirement homes. That research was carried out in 38 retirement homes, and the results showed that there are both positive and negative aspects implicit in the design of the buildings, which is all the more important because senior citizens spend a great deal of time indoors. Among other findings, they determined that closely following hygienic standards are crucial due to the increased susceptibility of the elderly to disease and infections and that particular care needs to be taken in the design of spaces where food is prepared and/or consumed (Torrington *et al*, 2004). Colombo and his colleagues (1998) analyzed 26 flats and identified the most commonly occurring problems facing the elderly. 33 % of the flats were identified as having kitchen-security issues, and 25 % as having inadequate lighting. Pinto et al, noted that one of the most common causes of injury in a home environment for the elderly is the changing of light bulbs if, in doing so, the elderly person has to stand on a chair or ladder (Pinto *et al*, 2000).

Research has also shown that due to social and financial reasons, a large percentage of senior citizens, especially those with movement impediments, tend to remain indoors for longer periods of time. This challenges the designers of living quarters regarding additional requirements, in particular how to facilitate movement for people with disabilities and how to improve their quality of life in general. The majority of flats are designed for young, fit, and active people. Many senior inhabitants do not possess these attributes, meaning that even performing the simplest home tasks is more taxing for them. Furthermore, inappropriately designed housing space can lead to health issues such as backache or injuries from accidents. Research has shown that adapting living space to the needs of the elderly can reduce the risk of injury by 30 % - 50 %. The age of the furniture and equipment in their homes also plays an important part in determining functionality. According to research, 60 % of the senior population lives in homes that have not been renovated or refurnished for over 20 years, contributing to lower safety and comfort levels, (Home Remodeling..., 2006). Comfort is crucial for the elderly, as they spend most of their time at home. Over 14 % of English elder citizens live in unfit conditions, in homes that are in dire need of renovation and adaptation (Boyo, 2001). Yet only 10 % of them decide to modify their existing furniture and equipment to reflect their special needs (Gilderbloom *et al*, 1996; Katsura *et al*, 1989). They often refrain from renovating due to financial concerns, lessening mobility and fear of the upheaval of renovation work. Furthermore, the research also shows that the elderly also suffer from inappropriate room dimensions including rooms that are too big for them (West and Emmitt, 2004).

According to data issued by the Statistical Office of the Republic of Slovenia, citizens over the age of 60 accounted for only 11.84 % of the changes made to residences in 2008. Other data suggests that senior citizens rarely decide to change their home environments, which contributes to a lowering of comfort levels and environments ill–suited for accommodating residents with special needs, and to lower safety levels. Most people are also reluctant to live in a retirement home, and only do so when they are entirely incapable of living by themselves. In Great Britain, only 4 % of citizens between the age of 65 and 69 live in a retirement home, 7 % between the age of 70 and 74, 10 % between 75 and 79, 13 % between 80 and 85 and 19 % of people older than 85 (National Statistics GB, 2003). In Slovenia, 7 % of the population resides in a retirement home. Of course, senior citizens who require aid at home have different design needs than those who are capable of living by themselves (Schwarz, 1997). A good solution is to design modern residential units with architectural and furniture elements that are ergonomically adjusted for elderly or handicapped users, from the standpoint of both safety and functionality. Boyo (2001) claims that 10 % of elderly users suffer from difficulties regarding kitchen mobility.The essence of design is to understand the specific needs and wishes of the end-users

Table 1 Respondent age
Tablica 1. Starost ispitanika

	55-59 years *godina*	60-64 years *godine*	65-69 years *godina*	70-74 years *godine*	75-79 years *godina*	80-84 years *godine*	85-89 years *godina*	90 + years *godina*	Total *Ukupno*
Women / *Žene*	42	27	25	25	16	11	7		153
Men / *Muškarci*	12	9	7	9	8	4	1	1	51
Women and Men together *Žene i muškarci, ukupno*	54	36	32	34	24	15	8	1	204

Table 2 Age of respondents' kitchens
Tablica 2. Starost kuhinja ispitanika

	Kitchen age / *Starost kuhinje*					
	Less than 5 years / *Manje od 5 godina*	5-9 years *godina*	10-14 years *godina*	15-19 years *godina*	20-29 years *godina*	More than 30 years / *Više od 30 godina*
Number of respondents *Broj ispitanika*	38	27	33	34	59	13
Share in percent, % *Udio u postocima*	19	13	16	17	29	6

(Margolin, 1997). The goal of the current research was to discover whether people are satisfied with the functionalities of their kitchens, whether they feel safe or not whilst using them and whether or not the degree of dissatisfaction increased with the respondents' age. Our desire was to establish the main issues that seniors face when using a kitchen and to establish criteria for improving the design of kitchen furniture tailored for the senior citizens, in order to give them greater independence, safety, and quality of life.

2 MATERIAL AND METHODS
2. MATERIALI I METODE

The research was carried out via individual surveys. The survey only included people over the age of 55. 210 questionnaires were filled in, of which 204 were valid. The respondents were aged between 55 and 91 (Table 1). Most respondents, 76 %, were aged between 55 and 74. The survey pool consisted of 75 % women and 25 % men. The questionnaire consists of 54 questions and is divided into 4 parts. In the first part, questions focus on general data of respondents' flats and number of people who live there. The second part of the questionnaire examines tasks in the kitchen. The third part collects functionality data concerning the kitchen and the last part examines consumer behavior. This paper has been focused on questions concerning security and functionality issues.

The majority of respondents (57 %) live in a single apartment home, whilst the remainder lives in houses with multiple apartments. When compared to the overall data for Slovenia, where 64 % of households exist in a single-apartment house, this represents a satisfactory sample (Statistical Office of the Republic of Slovenia, Census 2002).

The survey was carried out in the respondents' homes. Most questions were closed-ended, using a yes/no dichotomy, but some were multiple choice questions. Very few questions were open-ended, only the ones that were expected to provide the most varied array of answers. In regard to information about the proper arrangements of work surfaces and implements, the interviewer carrying out the survey answered the questions after receiving detailed instructions on how to assess the arrangement.

3 RESULTS
3. REZULTATI

We were interested in the age of the respondents' kitchen equipment. Table 2 shows that 35 % of respondents have a kitchen older than 20 years, whilst 52 % have a kitchen older than 15 years.

The respondents were asked whether they were satisfied with their kitchen, and the results are shown in Table 3. It is noteworthy that 72 % of them were satisfied with their kitchen arrangements, despite the fact that the majority of kitchens were inadequate in their functional or ergonomic designs.

Table 3 Satisfaction with the degree of kitchen functionality
Tablica 3. Prikaz zadovoljstva opremom kuhinje

	Yes *Da*	**No** *Ne*
Number of answers *Broj odgovora*	147	57
Percentage ratio, % *Postotni udje, %*	72	28

Figure 1 shows the results of the answers to the question as to what bothers the respondents the most in their kitchen. Only those who expressed dissatisfaction with their kitchens answered this question. They had the possibility to choose several negative factors. The respondents who answered that they were dissatisfied with the functionality of their furniture and lighting were asked to elaborate as to what in particular bothered them. They cited: inadequate lighting over the kitchen work surfaces and inside the cupboards, inap-

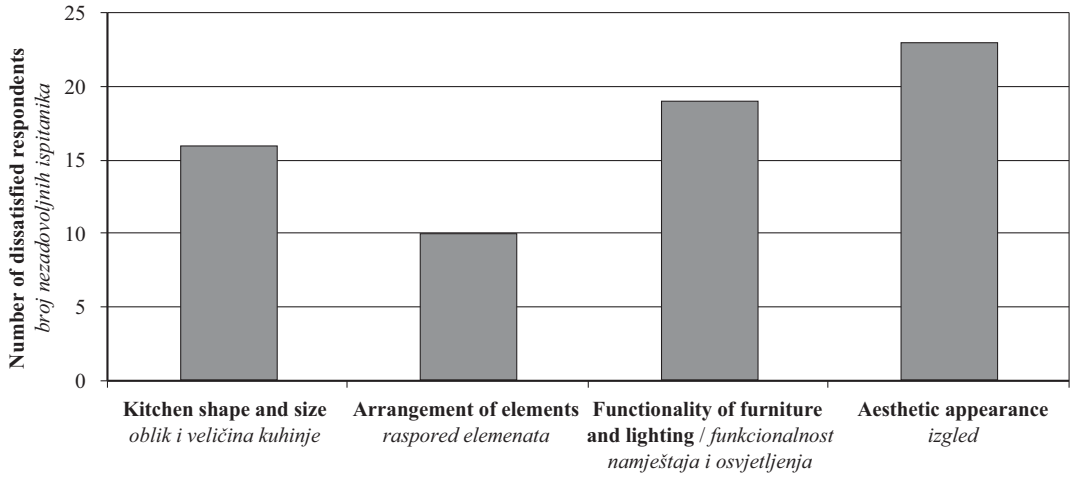


Figure 1 Graphical representation of respondents' dissatisfaction with kitchen elements
Slika 1. Grafički prikaz nezadovoljstva ispitanika kuhinjama

propriate height of shelves, oven, refrigerator, troublesome cleaning set-up (e.g. contact between wall and work surface, contact between work surface and kitchen appliances), inadequate handle design (e.g. too small, slippery, fall off, in the way), hard-to-reach places in the corners or shelves under the cupboards.

Figure 2 shows a succession of elements that we deem appropriate. We took into consideration the darkly colored parts. An appropriate width for a work surface was deemed to be between 60 and 150 cm. Over half (56 %) of the subjects had an inappropriate arrangement of the three main work areas (Table 4).

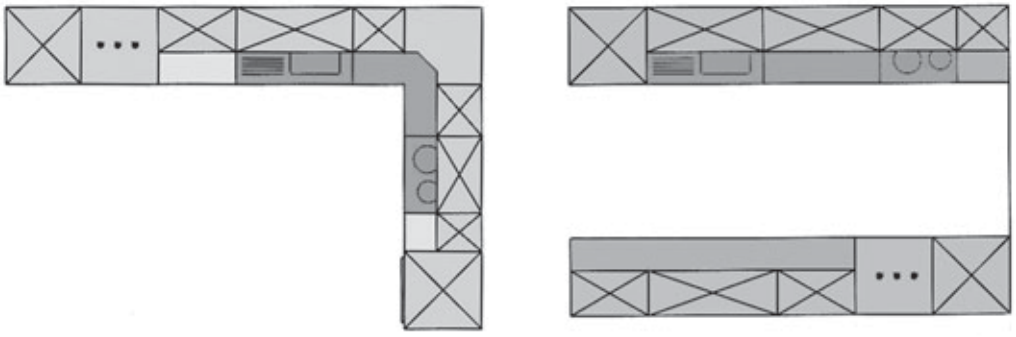
Table 4 Respondents' satisfaction with arrangement of the three main work areas and an adequate width of the main work surface
Tablica 4. Udjel ispitanika koji imaju primjeran redoslijed radnih zona i primjernu širinu radne površine

	Yes / *Da*	**No** / *Ne*
Adequate arrangement of main areas and adequate width of main work surface / *Primjeren redoslijed radnih zona i primjerena širina radne površine*	89	115
Percentage (%) / *Postotak*	44	56

We were interested in the degree to which senior users were prepared to use modern technology and computers. Out of 15 persons who stated they used a computer, 14 were younger than 65. A somewhat higher percentage (21 %) would be comfortable with using kitchen robots (Table 5).

When posed the question as to what caused them the most problems when cleaning their surfaces, the respondents indicated that most problems were caused by the transition between the stove and the work surface and the edges of the sink and stove.

Respondents were asked what caused them the most problems when cleaning their cupboards. Most reported problems are caused by the profiled surfaces of doors and decorative openings. Some 44 % of respondents chose this answer. A little fewer respondents (40 %) reported a problem cleaning the handles. Only 16 % have problems related to materials ill-suited for cleaning. Respondents were also given the option of listing other problematic elements, which included wall-mounted and corner cupboards, because the shelves are hard to reach, and the top sides of the tall and wall-mounted cupboards are too high to reach and clean easily. They find it hard to clean under raised cupboards, as well as cleaning the bottoms of the cupboards themselves.



a) L – shaped kitchen / *kuhinja u obliku slova L*

b) two – way kitchen / *dvostruko smještena kuhinja*

Figure 2 Adequate arrangement of three main work areas
Slika 2. Primjeren redoslijed radnih zona u kuhinji

Table 5 Percentage of respondents who use a computer and those who would be willing to use a kitchen robot
Tablica 5. Razmjer ispitanika koji upotrebljavaju kompjutor i onih koji bi bili spremni upotrebljavati kuhinjske robote

		Yes / *Da*	**No** / *Ne*
Do you use a computer at home? *Upotrebljavate li kompjutor kod kuće?*	Number of answers / *Broj odgovora*	27	177
	Percentage, % / *Postotak, %*	13	87
Would you be prepared to use kitchen robots? *Jeste li spremni upotrebljavati kuhinjske robote?*	Number of answers / *Broj odgovora*	43	161
	Percentage, % / *Postotak, %*	21	79

Senior citizens often tend to have bad eyesight. We asked the respondents whether or not their kitchen light sources were positioned correctly and whether or not they were placed in such a way to cast the user's shadow directly on to the area where work was performed. Table 6 shows that about a third (32 %) of the respondents have what they perceived to be inadequately lit work surfaces.

Table 6 Appropriateness of lighting source in regards to casting shadows
Tablica 6. Primjernost položaja rasvjete s obzirom na sjene

Are your light sources positioned so that the user's shadow is not cast onto work surfaces? / *Jesu li svjetla postavljena tako da sjena korisnikova tjela pada na radnu površinu?*	**Yes** *Da*	**No** *Ne*
Number of respondents / *Broj odgovora*	66	138
Percentage, % *Postotak, %*	32	68

We were interested in finding out how many respondents had light sources in their kitchen that required them to climb up on something to change bulbs. The results show that all but one respondent have such inappropriate light sources.

Many senior citizens suffer from bad memory. We asked the respondents whether or not they faced problems connected with bad memory whilst performing kitchen tasks, and if yes, in what specific ways. About a quarter (24 %) of respondents did not report having a bad memory, whilst the others claimed to suffer from this problem in the kitchen. Those that answered affirmatively were asked specifically how bad memory made their kitchen tasks harder to perform. Respondents were given the option of choosing multiple answers. 35 % of them had forgotten to buy all the ingredients required to cook a meal, 29 % had forgotten that they have food cooking, resulting in charred or burnt meals, 26 % had forgotten what ingredients they had already put in a meal (spices), whilst 10 % had forgotten to close the fridge door, turn off the stove or had left water running.

Senior citizens are less agile, having more difficulty moving around a room, which means they suffer from a greater risk of injury. We asked the respondents whether or not they bumped into open cabinet cupboard or sharp surface and table edges whilst performing kitchen tasks, such as preparing food or emptying the dishwasher. The results show that 72 % have had problems with bumping into doors or corners.

We were also interested in whether or not respondents had problems with slippery kitchen floors. The results show that most (60 %) do not have a slippery floor covering whilst others face this problem occasionally, particularly when the floor is wet. We noted the types of floor coverings the respondents used and concluded from this that most of those who claimed to have problems with slippery floors used either linoleum or ceramic tiles; two had a stone floor.

4 DISCUSSION
4. DISKUSIJA

It had originally been surmised that most senior users would be dissatisfied with the functionality of their kitchens. However, the majority of respondents (72 %) were indeed satisfied with their kitchen, despite the fact that 56 % of them were found to have unsuitably arranged work surfaces, trouble with maintaining a hygienic environment, that over a third had unsuitable lighting arrangements, and that over half of respondents (52 %) had kitchens older than 15 years. The results show that users are typically unaware that they could perform their daily tasks faster, with less effort, and a greater degree of safety.

Those that were dissatisfied with their kitchens again gave surprising results, since most were uncomfortable with aesthetics rather than functionality. It had been anticipated that senior users would be more dissatisfied by the functionality of their kitchen, as they tend to suffer from restricted agility, sight and/or memory issues. It appears that they become used to their kitchen and have limited desire for change. They typically attribute the problems they face when using their kitchen to their advancing age, but are unaware of the fact that their problems could be lessened if the space were adapted to their needs. Therefore we are of the opinion that householders over the age of 55 should already be looking into kitchens that are adapted for use by senior citizens so as to become accustomed to it whilst they are still active, and get used to new environments with greater ease.

Our research shows that 56 % of respondents have an inappropriate work surface arrangement. A more functional and safer kitchen working environment is gained by appropriately arranging its elements. Particularly important is the arrangement of the kitchen sink, the main work surfaces and stove, this being the part of the kitchen where most of the cooking process takes place. An appropriate arrangement is one which allows the user to remain in one spot whilst preparing food (slicing, cutting, peeling, washing), whilst and at

the same time monitoring the food that is already being cooked (stirring, adding). Additionally, the adjacent position of the sink and stove would mean that the user needs to travel a shorter distance if he or she needs to pour away boiling water.

It is assumed that in the future, so-called „intelligent" technology will make an important contribution to kitchen usage and will ease the workloads of users by a sizeable amount. The fact that very few of the respondents use a computer was to be expected and corresponds to the conclusion that most (79 %) would not want a robot in their kitchen to help out. Many senior users have trouble adapting to new technology, and most of them have no wish for it at all. At present, users over 65 years old are not potential customers for robotically-aided kitchens. In 10 years however, when 65 will be of an age at which people have become familiar with computers in their active years, a robotically-aided kitchen will be much more attractive to elderly users. It will be necessary however, as Casals et al. (2000) determined, to make the commands and controls simple, easy-to-use and user-friendly.

„Smart" kitchen appliances are a step in this direction. The research shows that 29 % of users who have memory issues tend to leave stoves on, which can easily create a fire hazard. From the point of view of safety, this means intelligent stoves with the option of setting cooking times and automatic shut-off systems when operating with an empty container or without one at all. Intelligent refrigerators are also a welcome addition, for example ones capable of ordering groceries on the internet via a display on the refrigerator door. The refrigerator monitors one's food inside via labels and barcodes, whilst also noting the purchase dates of products, and then warning about the expiry date. The use is not complicated, and as senior users tend to have problems with mobility, this addition could be of great help to them. Due to the senior users' difficulties in keeping up with new technologies it would be necessary to carefully select the appliances that are easy to use and have clear, intuitive interfaces.

The possibility of maintaining hygiene in a kitchen is of great importance for senior users, who are more susceptible to infection. The research findings indicate that they report trouble cleaning, in particular handles, profiled surfaces and unsuitable transitions between work-surfaces, walls and appliances. We therefore recommend smooth doors made of materials that are easy to clean. A good solution is a handle-free cupboard which opens by pressure alone. The surface should be entirely of one piece, with proper joint between work-surface and wall, with a sink and stove mounted to avoid gaps or thresholds that make cleaning harder.

Cupboards placed under work-surfaces with a base reaching fully to the floor facilitate cleaning, since senior users find it difficult to bend and sweep underneath cupboards. Similarly, the top sides of tall and wall-mounted cupboards are problematic areas, and therefore we advocate avoiding wall-mounted cupboards, preferably building them inside the walls themselves, if necessary.

Kitchen safety also relates to good lighting. An adequate light level for work surfaces is a necessity. By the contrast to the Slovenian data, research in Italy, Colombo et al. (1998) shows that 25 % of kitchens have inadequate lighting conditions. According to our data, the amount of inadequately lit kitchens among senior users in Slovenia is even greater - 32 %. Additionally, nearly all users have light sources that require climbing on to chairs or ladders to change light bulbs, which is why we recommend wall lamps and lamps with LED, which last for many years.

Senior users in US tend to have sight and agility problems, which compounds the problem of slippery floors in a kitchen. Every year, 30 % of users over the age of 65 experience a fall in their kitchen, a danger that can lead to serious injury or even death (Stevens, 2005). Additionally, such injuries account for a sizeable expenditure by the health services. The costs involved in reducing the risk of falls and providing for a safer environment would be comparably lower (Valente *et al*, 1998). To lower the risk of injury, walkways between rooms should not have thresholds or changes in elevation. Additionally, the floor covering should be non-slippery. Our research shows that as many as 72 % of users bump into open doors and various sharp edges during kitchen work. When designing a kitchen for the elderly, it should be taken into consideration that bumping into rounded edges is less painful and safer, which is why we advocate such a realization of edges, whilst sliding cabinet doors are preferable to the hinged variety, and entirely remove the problem of bumping into open doors.

5 CONCLUSIONS
5. ZAKLJUČAK

Most users who renovate their kitchen at an older age count on it being used for the rest of their lives. Yet the results of this research show that most people are unaware of the importance of ergonomic adaptations to the specific needs that old age brings. Manufacturers should design kitchen furniture systems that would allow for implementation adapted for special needs and should inform buyers more about the significance of an adequately furnished kitchen, heeding the needs of advanced age.

Kitchen design for the elderly should take into consideration the following:

– A carefully planned arrangement (correct succession) of elements and appliances, which allows for the straightforward, safe, and swift performance of tasks with the minimum required motion;
– To prevent falling, passages between rooms should be without changes in elevation and thresholds, whilst the floor should be non-slippery;
– Local lighting of all work surfaces should be such that no obstructing shadows are cast (e.g. own body, etc);

- Lighting where the user need not trouble themselves with changing light-bulbs (e.g. wall-mounted light sources, LED lighting);
- Furniture and counters with rounded edges;
- Materials and furniture design should allow for easy cleaning (e.g. smooth surfaces, rounded transitions, very few open shelves);
- For ease of cleaning, cabinets without handles are preferred, and if handles are included, they should be designed for users with lessened agility in mind, and should be easy to clean;
- It is advisable to use cupboards with bases that reach all the way to the floor and arrangements that prevent the gathering of dust and dirt on the top parts of hanging and tall cupboards;
- Wall-mounted cupboards with sliding doors;
- Stoves and ovens with automatic shut-off systems or with a signal light and sound, drawing attention to a hot element left unattended, as well as an option to set cooking times;
- Appliances must allow for easy and streamlined use and must include straightforward and intuitive commands. Control buttons must be in plain sight and adapted for users with deteriorating eyesight. Of particular importance is a clear indication as to whether the appliance is ON or OFF.

Considering that designers, when planning objects for home use, tend to have in mind the 19 to 65 age-group, we expected modern kitchen furniture to neglect the needs of the elderly. The research has identified the needs of the elderly and is, as such, of help to designers and architects when designing kitchen environments for the elderly. Therefore, our findings relate to the Dorst & Cross (2001), who for successful design recommend the interaction between goals and ideas. Due to the extensive nature of the subject, this research was chiefly concerned with the question of safety, whilst future research would elaborate on the subject of dimensional adequacy. The research will be carried out by a computer simulation model. The technology of 3D modeling is already being integrated into the design for other products Mijović *at al*. (2001) and Smardzewski (2009). The results of this research will be used to plan a kitchen that will allow for effective usage and provide safety and comfort to senior users. It will be developed in collaboration with one of the established kitchen manufacturers. The main objective of each company would be an efficient and successful operation. There is a general economic principle: to achieve the maximum result with the minimum of means (Oblak *et al*, 2008). The effective use of design can contribute positively to business performance (Bruce *et al*, 1999). During the congress „Wellness-Inseln zu Hause schaffen“ in Stuttgart, it has been pointed out that the „Best-Ager“ (45+) and „Silver-Ager“ (65+) demographic groups are strong buyers with high demands, making them groups that are rapidly gaining in significance (JN., 2003). In the future, we would broaden the research to include other parts of residential unit, thus providing criteria for the design of homes for the elderly.

6 REFERENCES
6. LITERATURA

1. Boyo, S. 2001: When a house is not a home. Older People and their housing, London: AGE – Age Concern England: 65.
2. Bruce, M.; Cooper, R.; Vazquez, D. 1999: Effective design management for small businesses, Design Studies. 20: 297-315 http://dx.doi.org/10.1016/S0142-694X(98)00022-2.
3. Colombo, M.; Vitali, S.; Molla, G.; Gioia, P.; Milani, M. 1998: The home environment modification program in the care of demented elderly, Arch. Gerontol.Geriatr. suppl. 6: 83-90 http://dx.doi.org/10.1016/S0167-4943(98)80015-0.
4. Casals, A.; Cufi, X.; Freixenet, J.; Marti, J.; Munoz, X. 2000: Friendly interface for objects selection in a robotized kitchen, ICRA 2000:IEEE International Conference on Robotics and Automation, San Francisco, 24-28. 4. 2000, Institute of Electrical and Electronics Engineers Inc.
5. Dorst, K.; Cross, N. 2001: Creativity in the design process: co-evolution of problem-solution, Design Studies 22: 425-437 http://dx.doi.org/10.1016/S0142-694X(01)00009-6.
6. Gilderbloom, J.I.; Affairs, U.; Markham, J.P. 1996: Housing Modification Needs of the Disabled Elderly: What Really Matters?, Environment and Behavior. 28(4): 512-535 http://dx.doi.org/10.1177/0013916596284005.
7. Hilderbrand, H. 2002: Für Ältere und Behinderte, BM. 57 (3): 36 .
8. JN. 2003: Wohnst du noch oder lebst du schon, dds Das magazin für möbel und ausbau. 84 (6): 80-81.
9. Margolin, V. 1997: Getting to know the user, Design Studies. 18: 277-236 http://dx.doi.org/10.1016/S0142-694X(97)00001-X.
10. Oblak, L.; Jelačić, D.; Motik, D.; Grladinović, T. 2008: A model for stock management in a wood-industry company, Wood research. 53(1): 105-116.
11. Mijović, B.; Ujević, D.; Baksa, S. 2001: Visualization of Anthropometric Measures of Workers in Computer 3D Modeling of Work Place, Collegium Antropol. 25 (1): 639-650
12. Pinto, M.R.; De Medici, S. 2000: Ergonomics, gerontechnology, and design for the home-environment, Applied Ergonomics. 31 (3): 317-322 http://dx.doi.org/10.1016/S0003-6870(99)00058-7.
13. Schwarz, B. 1997: Nursing home design: a misguided architectural model, Journal of Architectural Planning and Research. 14(4): 343-359.
14. Smardzewski, J. 2009: Antropotechnical aspects of furniture design, Drvna Industrija. 60 (1) 15-21.
15. Stevens, J. A. 2005: Falls Among Older Adults – Risk Factors and Prevention Strategies, Journal of Safety Research. 36(4): 409-411 http://dx.doi.org/10.1016/j.jsr.2005.08.001.
16. Torrington, J.; Barnes, S.; Kevin, M.; Kevin, M.; Tregenza, P. 2004: The influence of Building Design on the Quality of Life of Older People, Architectural Science Review. 47(2): 193-197.
17. Valente, J.; Dignam, T.; Marchman, K.; Mary, C. 1998: Description of a Model Rural, Older Adult Injury Prevention Program for the Home, Housing and Society. 25, (1-2): 53-66.
18. West, B.N.; Emmitt, S. 2004: Functional design? An analysis of new speculative house plans in the UK. Design Studies. 25: 275-299 http://dx.doi.org/10.1016/j.destud.2003.10.002.
19. ***2003: National Statistics GB. 2003 People living in sheltered accommodation by age and household type General Household Survey, table 7 (online). http://www.

ageconcern.co.uk/AgeConcern; Facts, figures & research, housing (18.8 2006)
20. ***13.05.2010: Population by age groups and sex, statistical regions, Slovenia, annually. 2010, Statistical Office of the Republic of Slovenia (online) http://www.stat.si/pxweb/Dialog/varval.asp?ma=0520308E&ti=Population+by+age+groups+and+sex%2C+statistical+regions%2C+Slovenia%2C+annually&path=../Database/Demographics/05_population/02_05007_numb_struct/01_05203_age_sex/&lang=1
21. ***(12.07.2010) 2008: Net migration and total increase of population by statistical regions (indicators), Slovenia, annually., Statistical Office of the Republic of Slovenia (online)
22. ***http://www.stat.si/pxweb/Dialog/varval.asp?ma=0515602E&ti=Net+migration+and+total+increase+of+population+by+statistical+regions+%28indicators%29%2C+Slovenia%2C+annually&path=../Database/Demographics/05_population/04_05156_migrations/00_05156_indicators/&lang=1 (19.07.2009).
23. ***2005: Home Remodeling - Why Is Home Modification And Repair Important? (online) http://www.aoa.gov/eldfam/Housing/Home_Remodeling/Home_Remodeling.asp;(17.8.2006)
24. ***2002: Population Census results. 2002, Households in dwellings by tenure status, type of building, number of rooms, useful floor space, utility spaces, installations and type of settlement, Slovenia, Statistical Office of the Republic of Slovenia (online)
25. ***http://www.stat.si/popis2002/si/rezultati/rezultati_red.asp?ter=SLO&st=44 (19.07.2009).

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Shrinkage of Grand Fir Wood and its Variability within the Stem

Utezanje drva jele i njezina varijabilnost u stablu

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ABSTRACT • *This study presents the results of the experiment focused on assessment of the shrinkage of Grand fir (Abies grandis /Douglas/ Lindl.) wood and its variability in relation to the position in the stem. The examined sample trees came from the Černokostelecka Area in the Czech Republic. Tangential shrinkage was 7.1 %, radial 3.3 % and volumetric shrinkage 10.5 %. The results show evident influence of the horizontal position on the evaluated features. The lowest shrinkage values are attained close to the pith; shrinkage toward the bark shows a rising trend. In terms of vertical position, the distribution of shrinkage in the stem did not show any apparent trend. Although the dependence of shrinkage on density proved to be statistically significant, density explains only a small portion of the shrinkage variability..*

Key words: *Grand fir (Abies grandis /Douglas/ Lindl.), shrinkage, density, introduced species, variability*

SAŽETAK • *U radu se prikazuju rezultati istraživanja usmjerenih na ocjenu utezanja drva jele (Abies grandis / Douglas/ Lindl.) i varijabilnost utezanja s obzirom na mjesto uzorka u stablu. Jelovo drvo na kojemu su provedena istraživanja potječe s područja Černokostelecka u Republici Češkoj. Tangencijalno utezanje drva bilo je 7,1 %, radijalno 3,3 % a volumno 10,5 %. Rezultati pokazuju velik utjecaj horizontalnog položaja uzorka na istraživana obilježja. Najniže vrijednosti utezanja drva izmjerene su na uzorcima koji su blizu srži, a uzorci koji su bliže kori pokazuju rastući trend utezanja. S obzirom na vertikalan položaj uzorka u stablu, nije zabilježen očit trend raspodjele utezanja. Iako se ovisnost utezanja o gustoći pokazala statistički signifikantnom, gustoća opisuje samo manji dio varijabilnosti utezanja jelovine.*

Ključne riječi: *drvo jele (Abies grandis /Douglas/ Lindl.), utezanje, gustoća, vrsta drva, varijabilnost*

1 INTRODUCTION
1. UVOD

Central European forest management is characterized by dominant usage of autochthonic forest woody plants. Silver fir (*Abies alba* /Mill.) has for centuries ranked among the most significant European trees. Due to its favorable growth and technological properties for the forest and wood industry, it was hardly replaceable. In comparison with the initial natural presence in the forest vegetation of the Czech Republic of 19.8 %, its current portion is about 1 % (MZE 2010). Beran (2006) states the clear absence of Silver fir in the Czech forests in age groups 40 – 60 years. In connection with massive recession of Silver fir from the Central European localities, extensive research was started already in the last century

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for the purpose of finding a tree, which could substitute the favorable characteristics of Silver fir.

Grand fir (*Abies grandis* /Douglas/ Lindl.) was selected based on positive references as one of the possible trees because of small site requirements, resistance and above-average volume production (Beran and Šindelář, 1996; Šindelář *et al*, 2006; Podrázský and Remeš, 2008; Podrázský and Remeš, 2009; Mitze, 2010). The natural habitat of Grand fir is the Northwest coast of North America. The climatic conditions in its natural habitat range from mild maritime to downright continental climate (Foiles *et al*, 1991; Alden, 1997; Klinka, 2007). Grand fir is considered in the Central European region to be a prospective introduced tree species. The quick and high volume yield coupled with the lower density predetermines this species for efficient industrial application (Hapla, 2006; Vos and Kharazipour, 2010; Hof *et al*, 2008; Mitze, 2010). In terms of growth and production, Grand fir is being monitored in many experiments and provenance tests. Current research supports its possibilities and growth potential mainly in juvenile years (König, 1995; Podrázský and Remeš 2008; Rau *et al*. 2008; Hof *et al*, 2008).

One of the most important physical properties of wood is shrinkage. This is a process in which the water in the cell walls evaporates from the wood resulting in dimensional and volume changes. Shrinkage describes the intensity of these changes in the wood. Wood shrinkage has a substantially anisotropic character (Bosshard, 1974; Požgaj *et al*, 1997; Niemz, 1993). Shrinkage is most intensive in the transverse directions, mainly in the tangential direction. Knowledge of the shrinkage values is fundamental for quality drying of the wood, hydrothermal treatment, impregnation, assurance of shape consistency and quality processing and working of the wood including surface finishes. Shrinkage of the wood continues to be a wood research subject (Kärki, 2001; Pelz *et al*, 2003; Riebel, 2007; Kord *et al*, 2010).

Wood as an organic material of plant origin shows substantial variability of properties (Josza and Middleton, 1994; Hapla and Wellhausen, 2003). The different shrinkage values in relation to the position in the trunk are confirmed by many authors (Ying *et al*, 1994; Dumail and Castera, 1997; Kärki, 2001; Perstorper *et al*, 2001; Wang *et al*, 2008; Yamashita *et al*, 2009; Kord *et al*, 2010; Leonardon *et al*, 2010). Wood density can be considered the key indicator of wood quality. From the density value, it is possible to derive other significant mechanical and physical properties of wood that are also important for practice (Bosshard, 1974; Niemz, 1993; Požgaj *et al*, 1997; Niemz and Sonderegger, 2003). This dependence can also be found between density and shrinkage.

This is one of the results of the extensive study focused on the assessment of the quality of Grand fir wood in the Czech Republic. The main idea of the experiments was to evaluate the position of Grand fir among the domestic firs, and acquire data for the application of Grand fir wood in the wood processing industry. Last but not least, the assessment was to be made of the possibilities for replacing the domestic fir wood. The objective of this work was to determine the shrinkage of grand fir wood from the Czech Republic and to establish its trunk variability in relation to the vertical and horizontal position. The dependence of shrinkage on density was also evaluated.

2 MATERIAL AND METHODS
2. MATERIJALI I METODE

The locality for the collection of Grand fir sample trees was situated close to Kostelec nad Černými lesy village. The territory lies at a distance of 25 – 50 km south-east of Prague. The height above sea level of these localities is in the range of 325 – 430 m. A closer description of the localities is given by Podrázský and Remeš (2009) and Tauchman *et al*. (2010). A total of six representative Grand fir specimens were taken from

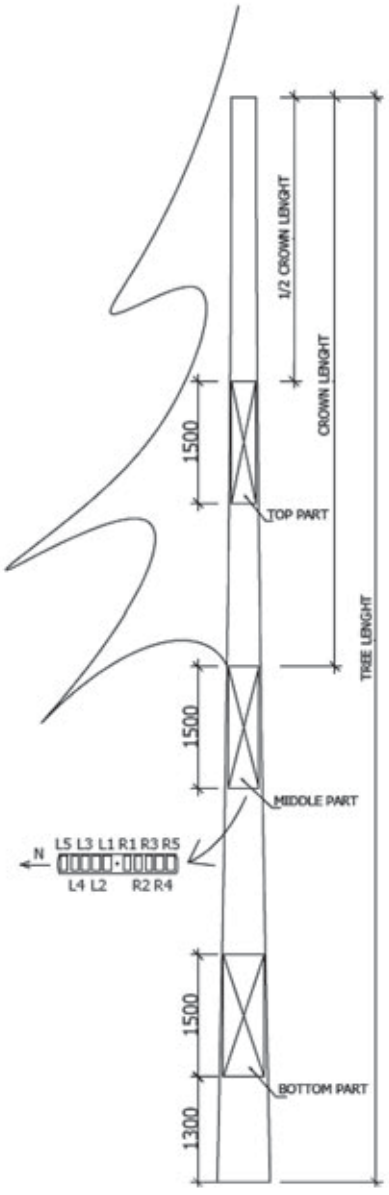

Figure 1 Tree sampling and horizontal position of the plank testing samples
Slika 1. Uzimanje uzorka iz stabla i horizontalan položaj uzorka u odsječku stabla

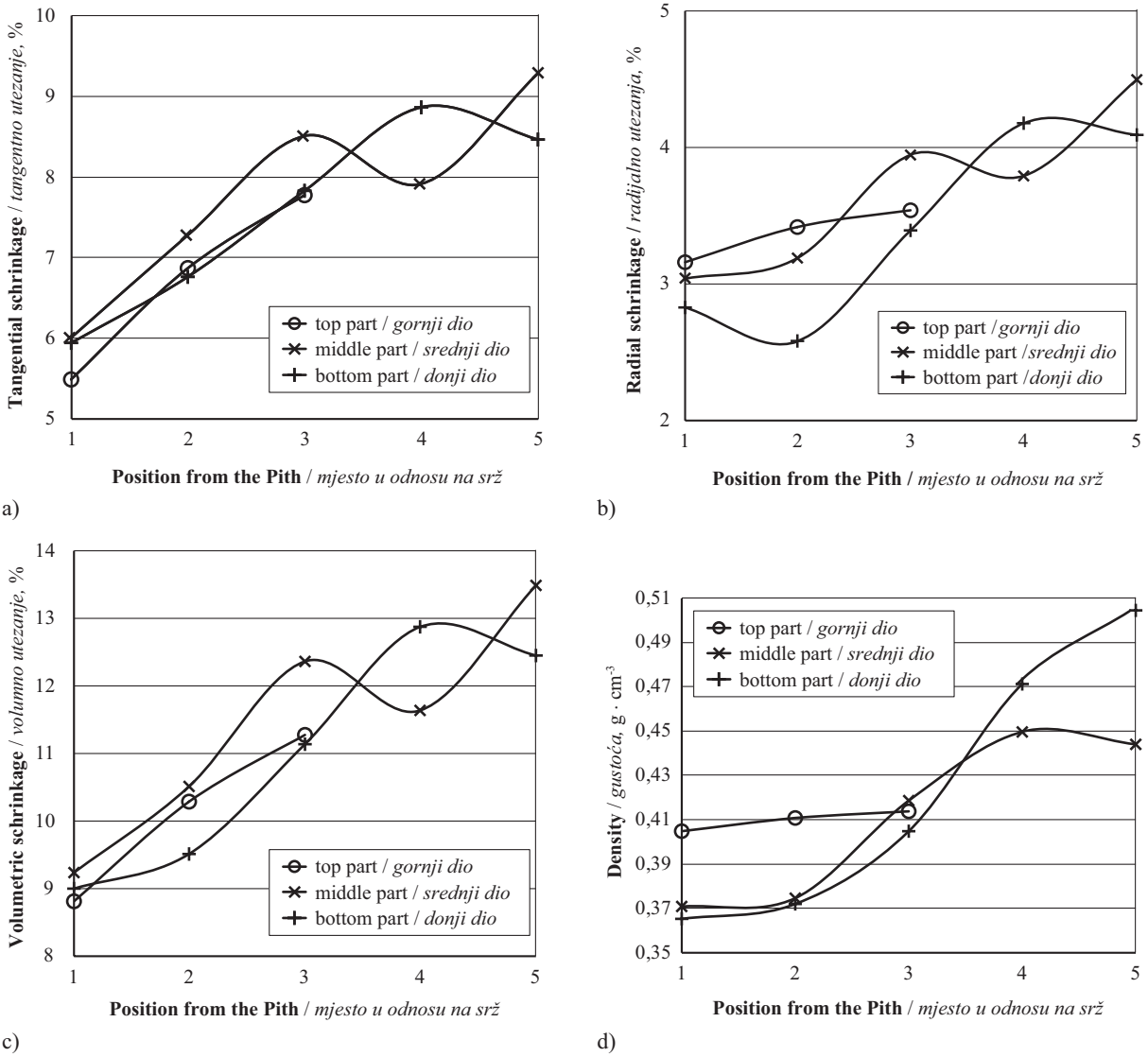

Figure 2 Dependence of tangential (A), radial (B), volumetric shrinkage (C) and density (D) on the trunk horizontal position
Slika 2. Ovisnost tangencijalnoga (A), radijalnoga (B) i volumnog utezanja (C) te gustoće (D) o horizontalnom položaju uzorka u stablu

several different stands in this area. The age of the felled trees was in the range of 29 – 38 years. The height of the sample trees was in the range of 24 - 30 m and the breast-height diameter in the range of 27 - 36 cm.

Three sections were always taken from the trunks of the felled trees - bottom, middle and top part (Vytisková, 1973; Langum *et al*, 2009). The sections represent different vertical positions in the trunk. When taking the specimens, the initial orientation in the plants was considered in terms of horizontal position (Sonderegger *et al*, 2008).

The centre planks were taken from individual sections, and test samples were subsequently prepared in a manner that enabled clear identification of their trunk horizontal position (Gryc and Horáček, 2007; Sonderegger *et al*, 2008; Langum *et al*, 2009). Numbers 1, 2, 3, 4, 5 show relative position to the pith, where number 1 means the closest position to the centre of the tree. A closer definition of the method for collecting sections and positions of the test samples in the section is given in Figure 1. Production of the test samples and subsequent wood testing were done in accordance with the national standard (ČSN 49 0101, 1980) in a laboratory with a controlled climate. The test samples used had the shape of squared timber of dimensions 20 mm x 20 mm x 25 ± 5 mm in tangential, radial and axial direction, respectively.

For each sample, the density was set at 12 % moisture content (ČSN 49 0108, 1993) and subsequently shrinkage in a tangential direction, radial direction and volume shrinkage (ČSN 49 0128, 1989). Total shrinkage, from green state to owen dry condition, was always evaluated in the respective direction.

3 RESULTS
3. REZULTATI

The average shrinkage value in the tangential direction was 7.1 % and in the radial direction 3.3 %. Volume shrinkage was 10.5 %. The rest of the descriptive statistics values for shrinkage in the individual anatomical directions and volume shrinkage are given in Table 1.

The progress of tangential shrinkage in relation to the trunk horizontal position shows a rising trend regardless of the vertical position and thus reaches the

Table 1 Descriptive statistics for shrinkage of *Abies grandis* wood
Tablica 1. Deskriptivna statistika vrijednosti utezanja jelova drva

Shrinkage, % *Utezanje, %*	**Valid N** *Broj uzoraka*	**Mean** *Srednja vrijednost*	**Minimum** *Najmanja vrijednost*	**Maximum** *Najveća vrijednost*	**Standard deviation** *Standardna devijacija*	**Coefficient of variation** *Koeficijent varijacije*
Tangential *tangencijalno*	595	7.1	1.7	10.6	1.4	19.8
Radial *radijalno*	595	3.3	0.7	7.5	0.8	24.4
Volumetric *volumno*	595	10.5	3.9	16.7	1.8	17.4

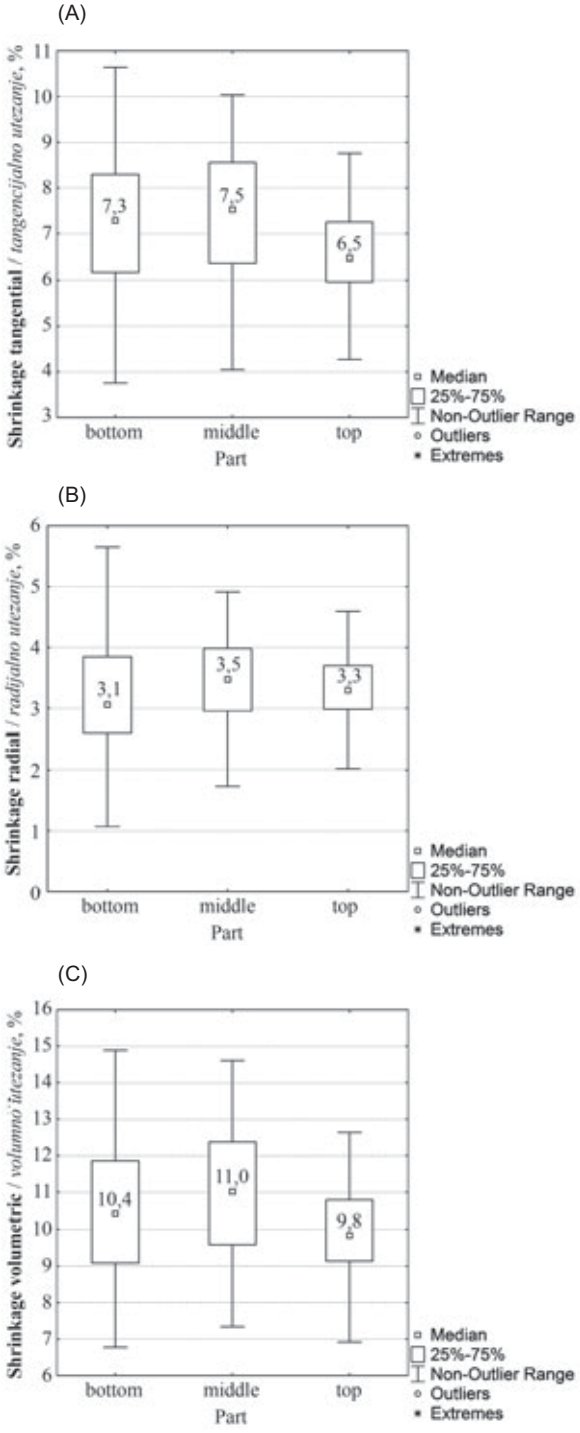

Figure 3 Dependence of tangential (A), radial (B) and volumetric (C) shrinkage on the trunk vertical position
Slika 3. Ovisnost tangencijalnoga (A), radijalnoga (B) i volumnog utezanja (C) o vertikalnom položaju uzorka u stablu

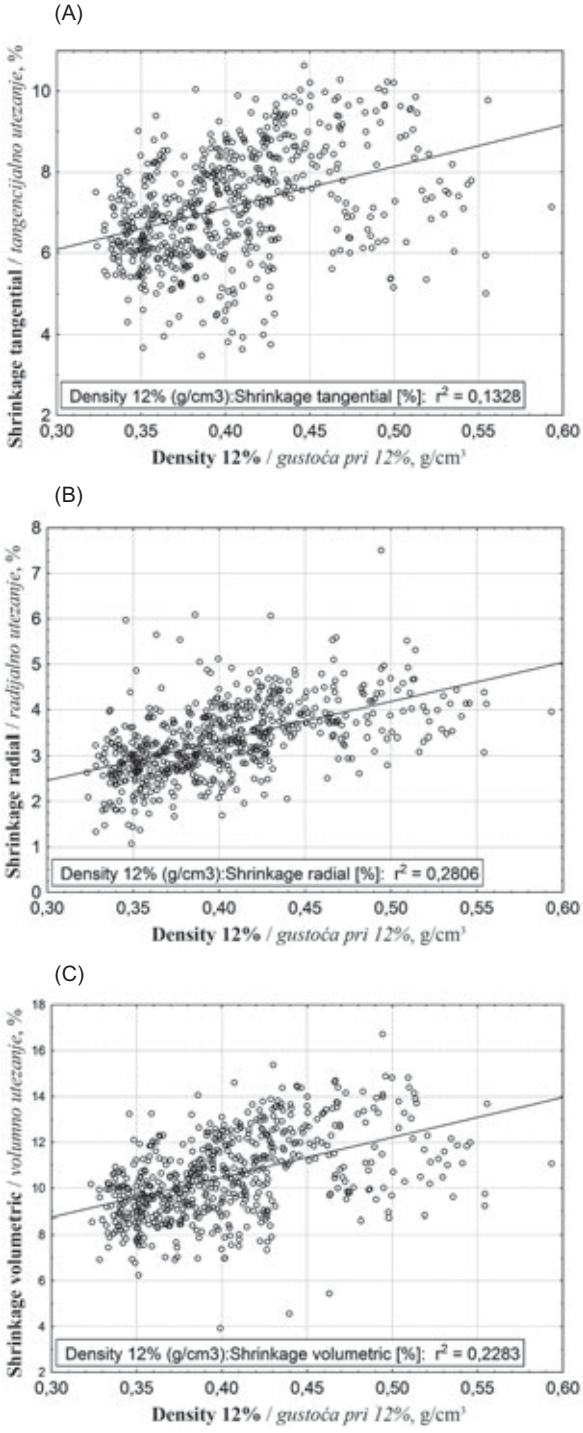

Figure 4 Dependence of tangential (A), radial (B) and volumetric (C) shrinkage on density (12 % MC)
Slika 4. Ovisnost tangencijalnoga (A), radijalnoga (B) i volumnog utezanja (C) o gustoći uzorka (uz 12 % sadržaja vode)

highest value in the zone furthest from the trunk pith. A similar trend is also observed in radial shrinkage and volumetric shrinkage (Figure 2). Density shows a similar trend to shrinkage, whereby it rises from the pith to the cambium (Figure 2). The most intensive rise in density appears in the bottom section of the trunk, while the mildest is in the top section.

Vertical variability does not have a clear trend in the case of radial shrinkage. The shrinkage values initially rise with height, and then drop towards the top. The lowest radial shrinkage value in the vertical direction is in the bottom section of the trunk. The highest shrinkage value is in the middle section of the trunk. ANOVA (Tukey test, $\alpha = 0.05$) confirmed the statistically significant difference in the radial shrinkage values between the middle and the bottom sections. Tangential shrinkage is also highest in the middle section of the trunk, the lowest shrinkage values are, however, reached in the top section. The top section shows statistically the lowest tangential shrinkage values. Volumetric shrinkage copies the trend of tangential shrinkage. The lowest shrinkage values are in the top section and the lowest in the middle section of the trunk. The top section shows statistically slower volumetric shrinkage values in comparison with the bottom or middle section. Radial, tangential and volumetric shrinkage has a comparable trend in the vertical direction. Shrinkage initially rises towards the middle section of the trunk and then slightly drops towards the top (Figure 3).

Although the relationship between shrinkage and density has been confirmed as statistically significant, the influence of density on the shrinkage of Grand fir wood is relatively low. The influence of density is most significant on radial shrinkage. However, the determination coefficient is only 0.28. In the remaining two instances of shrinkage evaluation, the values are even lower, 0.23 for volumetric shrinkage and only 0.13 for tangential shrinkage (Figure 4).

4 DISCUSSION
4. RASPRAVA

The ascertained shrinkage values for Grand fir from the locality in the Czech Republic correspond to the values attained in the natural habitat. Principally, identical values were obtained for both anatomical directions and volumetric shrinkage (Table 2).

Table 3 shows the comparison of the ascertained values with the quality of grand fir wood from the plantations in the rest of the European countries. It is clear that the shrinkage values of Grand fir in the Czech Republic are similar to those obtained by the authors who evaluated the shrinkage of this introduced wood tree grown in the neighbouring states.

The comparison with our native and commercial softwoods that Grand fir could suitably supplement or even replace is contained in Table 4. In terms of shrinkage values in the individual anatomical directions and volumetric shrinkage, Grand fir is closest to our domestic Silver fir. Riebel (2007) also arrived at the same conclusion. From just the shrinkage aspect, Grand fir is a suitable replacement.

In terms of shrinkage progress in grand fir trunk in the horizontal direction, the lowest shrinkage value is obtained near the pith. This distribution of shrinkage in the trunk is more or less similar for tangential, and radial as well as volumetric shrinkage. With the exception of the bottom section in the case of radial shrinkage, the vertical position has no influence and shrinkage shows a rising trend from the pith to the bark regardless of the section. The radial distribution of the density copies the shrinkage progress, whereby the lowest

Table 2 Comparison of shrinkage values with the values in the natural habitat
Tablica 2. Usporedba dobivenih vrijednosti utezanja s vrijednostima utezanja drva iz prirodnog staništa

	Simpson, TenWolde (1999)	**Lukášek *et al.***
Shrinkage tangential, % *Tangencijalno utezanje, %*	7.5	7.1
Shrinkage radial, % *Radijalno utezanje, %*	3.4	3.3
Shrinkage volumetric, % *Volumno utezanje, %*	11.0	10.5

Table 3 Comparison of shrinkage values with the values of the rest of the European plantations
Tablica 3. Usporedba dobivenih vrijednosti utezanja s vrijednostima utezanja za drvo s europskih plantaža

	Pelz *et al*, 2003	**Riebel, 2007**	**Lukášek *et al.***
Shrinkage tangential, % *Tangencijalno utezanje, %*	7.2 – 7.5	-	7.1
Shrinkage radial, % *Radijalno utezanje, %*	2.5 – 3.5	-	3.3
Shrinkage volumetric, % *Volumno utezanje, %*	-	10.7	10.5

Table 4 Comparison of shrinkage values with the values of the native softwoods grown in the Czech Republic
Tablica 4. Usporedba dobivenih vrijednosti utezanja s vrijednostima utezanja za domaće vrste mekog drva koje rastu u Republici Češkoj

	***Abies grandis* (Lukášek et al.)**	***Abies alba* ***	***Picea abies* ***	***Pinus silvestris****
Shrinkage tangential, % / *Tangencijalno utezanje, %*	7.1	7.2 – 7.6	7.8 – 8.0	7.5 – 8.7
Shrinkage radial, % / *Radijalno utezanje, %*	3.3	2.9 – 3.8	3.5 – 3.7	3.3 – 4.5
Shrinkage volumetric, % / *Volumno utezanje, %*	10.5	10.2 – 11.5	11.6 – 12.0	11.2 – 12.4
Density 12%, kg·m^{-3} / *Gustoća pri 12%, kg·m^{-3}*	405	450	470	510

* Wagenführ 2000

shrinkage value is near the pith, regardless of the vertical position, and has a rising trend toward the bark. The rising shrinkage values from the pith toward the bark are confirmed by Herritsch (2007), Wang *et al*. (2008). This phenomenon is attributed mainly to the presence of juvenile wood in the central zone of the trunk, and to the different microfibril angle of the cell wall of the juvenile wood in comparison with the angle of mature wood (Panshin and De Zeeuw, 1980; Larson *et al*, 2001; Perstoper *et al*, 2001; Yamashita *et al,* 2009; Leonardon *et al*, 2010).

Concerning the influence of the vertical position in the trunk on shrinkage distribution, a marked trend is not discernible in the case of Grand fir. Mild rise in the shrinkage from the bottom to the tree-top is in the middle section of the trunk replaced by a mild drop. With the exception of radial shrinkage, statistically the lowest value is obtained in the upper section of the trunk. The ambiguous trend in the vertical distribution of the dimensional changes of wood in the trunk in relation to the change of moisture content is confirmed by Gryc *et al*. (2007) and Wang *et al*. (2008). Just like in the case of radial variability, the vertical progress of the features is influenced by the portion of juvenile wood in individual trunk sections and its structural difference from mature wood (Zobel and Van Buitenen, 1989). A relatively surprising factor is the vertical progress of density, whereby its value rises with rising height and is the highest at the top part. Higher values of density in the upper section of the trunk are given by Dumail and Castera (1997). A different statistical density value is only in the middle section of the trunk. The differences in the density values in the bottom section and the top section cannot, however, be statistically proven (ANOVA, Tukey test, $\alpha = 0.05$) and it is not possible to talk about any significant trend in dependence of density on vertical position. The small influence of tree height on density is confirmed by Herritsch (2007) for *Pinus radiata*.

Shrinkage of both juvenile and mature wood is closely correlated to the wood density (Panshin and De Zeeuw 1980; Larson *et al*. 2001). Positive correlation of density and shrinkage was found by Bengtsson (2001), Perstoper *et al*. (2001) and Yamashita *et al*. (2009). The influence of density on the shrinkage of Grand fir wood is relatively low and is the most significant in radial shrinkage (Figure 4). The low value of the determination coefficient for the dependence of shrinkage on density is given by Kärki (2001). Niemz and Sonderegger (2003) state the determination coefficient for tangential swelling in relation to the density of wood at an average value of 0.39 for selected industrially processed woods. Also Kord *et al*. (2010) state a determination coefficient of 0.39 for the dependence of tangential shrinkage on wood density.

5 CONCLUSION
5. ZAKLJUČAK

The conclusions of this study targeted at the assessment of the shrinkage of Grand fir wood and its variability within the stem from the selected area in the Czech Republic are as follows:

- The shrinkage values for Grand fir in the climatic conditions of the Czech Republic correspond to the values obtained in the natural habitat.
- The shrinkage values are identical to those obtained in other European countries.
- Based on the shrinkage, Grand fir wood from domestic trees is the closest to the Silver fir wood.
- The influence of radial position on shrinkage variability was clearly proved, whereby the lowest values of all the assessed shrinkages are obtained in the centre of the trunk and rise towards its outer perimeter.
- The vertical position does not clearly influence the size of the shrinkage, whereby it was not possible to monitor the significant trend in the distribution of the shrinkage over the height of the trunk.
- The positive dependence of all the evaluated types of shrinkage on density was proven. The usage of the density value as an indicator of the degree of shrinkage is, however, disputable because the ascertained determination coefficients are relatively low.
- In terms of the overall concept of research focused on the evaluation of Grand fir wood quality, consequences for its processing and possibilities for its application, it can be concluded that Grand fir is a potential substitute for the indigenous Silver fir. However, this is a partial conclusion only based on comparison of shrinkage. Due to the substantially lower density in comparison with the domestic fir, additional tests shall be done, mainly of mechanical characteristics, and a complex comparison of these species will be performed.

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6 REFERENCES
6. LITERATURA

1. Alden, H. A., 1997: Softwoods of North America. Gen. Tech. Rep. FPL–GTR–102. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.
2. Bengtsson, CH., 2001:Variation of moisture induced movements in Norway spruce (*Picea abies*) Ann. For. Sci. 58(5): 568-581 http://dx.doi.org/10.1051/forest:2001146.
3. Beran, F., 2006: Některé poznatky z hodnocení mezinárodního provenienčního pokusu s jedlí obrovskou – Abies grandis /Douglas/ Lindl. Douglaska a jedle obrovská - opomíjení giganti, Sborník recenzovaných referátů. Kostelec nad Černými lesy. Česká zemědělská univerzita v Praze, Fakulta lesnická a enviromentální, Katedra pěstování lesů a Školní lesní podnik v Kostelci nad Černými lesy. 17-28.
4. Beran, F.; Šindelář, J., 1996: Perspektivy vybraných cizokrajných dřevin v lesním hospodářství České republiky. Lesnictví-Forestry. 42(8): 337-335.

5. Bosshard, H., 1974: Holzkunde: band 2 Zur Biologie, Physik und Chemie des Holzes. Basel und Stuttgart: Birhäuser Verlag.
6. Dumail, J.F.; Castera, P., 1997: Transverse Shrinkage in maritime pine juvenile wood. Wood Science and Technology. 31: 25-264 http://dx.doi.org/10.1007/BF00702613.
7. Foiles, M. W.; Graham, R.T.; Olson, D.F., 1991: Grand Fir. Silvics of North America: Conifers. United States Forest Service. 52-68.
8. Gryc, V.; Horáček, P. 2007: The Variability of Spruce (*Picea abies /L./Karst.)* Wood density with Present Reaction Wood. Journal of Forest Sciences. 53(3): 129-137.
9. Gryc, V.; Vavrčík, H.; Horáček, P., 2007: Variability in swelling of spruce (*Picea abies* [L.] Karst.) wood with the presence of compression wood. Journal of forest science, 53(6): 243-252.
10. Hapla, F., 2006: Use- and Wood Product- orientated Investigation on Abies grandis of different growth dynamics: An experimental Design. Kurjatko, S.; Kúdela, J.; Lagaňa, R. Wood Structure and Properties ´06. Zvolen. Arbora Publishers. 51-52.
11. Hapla, F.; Wellhausen, K., 2003: Verwendungsrelevante Holzeigenschaften und Verwendungsbereiche der Großen Küstentanne – Abies grandis (Douglas) Lindley – mit Aufkommensanalyse im Staatswald Niedersachsen. Institut für Holzbiologie und Holztechnologie, Universität Göttingen.
12. Herritsch, A., 2007: Investigations on Wood Stability and Related Properties of Radiata Pine. University of Canterbury. Disertation thesis.
13. Hof, CH.; Kielmann, B., C.; Hapla, F., 2008: Verwendungsorientierte Untersuchungen am Schnittholz der Abies grandis. Holztechnologie. 49(6): 7-11.
14. Jozsa, L., A.; Middleton, G. R., 1994: A discussion of wood quality attributes and their practical implications. Vancouver. Forintek Canada Corp.
15. Kärki, T., 2001: Variation of wood density and shrinkage in European aspen (*Populus tremula).* Holz als Roh- und Werkstoff. 59: 79-84 http://dx.doi.org/10.1007/s001070050479.
16. Klinka, K., 2007: Die Grosse Küstentanne (*Abies grandis* Lindl.) in Kanada und in den USA. Forst und Holz. 62(7): 10-13.
17. König, A., 1995: Geographic Variation of Abies grandis - Provenances Grown in Northwestern Germany. Silvae Genetica. 44(5–6): 248-255.
18. Kord, B.; Kialashaki, A.; Kord, B., 2010: The within-tree variation in wood density and Shrinkage, and their relationship in Populus euramericana. Turk J Agric For. 34: 121-126.
19. Langum, CH., E.; Yadama, V.; Lowell, E. C., 2009: Physical and Mechanical Properties of Young-Growth Douglas-Fir and Western Hemlock from Western Washington. Forest Products Journal. 59(11/12): 37-47.
20. Larson, P. R.; Kretschmann, D. E.; Clark, Alexander III; Isebrands, J.G., 2001: Formation and properties of juvenile wood in southern pines: a synopsis. Gen. Tech. Rep. FPL-GTR-129. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.
21. Leonardon, M.; Altaner, C. M.; Vihermaa, L.; Jarvis, M. C., 2010. Wood schrinkage: influence of anatomy, cell wall architecture, chemical composition and cambial age. Eur. J. Wood Prod., 68: 87-94 http://dx.doi.org/10.1007/s00107-009-0355-8.
22. Mitze, H., 2010: Ein unterschätzer Nordamerikaner: Küstentanne. Forstwirtschaft: Land & Forst., 26: 66-67.
23. Niemz, P., 1993: Physik des Holzes und der Holzwerkstoffe. Weinbrenner: DRW- Verlag.
24. Niemz, P.; Sonderegger, W., 2003: Untersuchungen zur Korrelation ausgewählter Holzeigenschaften untereinander unt mit der Rohdichte unter Verwendung von 103 Holzarten. Schweizerische Zeitschrift für Forstwesen, 12: 489-493 http://dx.doi.org/10.3188/szf.2003.0489.
25. Panshin, A. J.; De Zeeuw, C., 1980: Textbook of wood technology. 4th edition, New York: Mc-Graw-Hill.
26. Pelz, S.; Mehlin, I.; Becker, G.; Bücking, M., 2003: Eigenschaften und Verwendungsoptionen von *Abies grandis* und *Abies procera*: Zusammenfassende Ergebnisse einer Literaturstudie. Forst und Holz, 58(10): 290-296.
27. Perstorper, M.; Johansson, M.; Kliger, R.; Johansson, G., 2001: Distortion of Norway spruce timber: Part 1. Variation of relevant wood properties. Holz als Roh- und Werkstoff, 59: 94-103 http://dx.doi.org/10.1007/s001070050481.
28. Podrázský, V.; Remeš, J., 2008: Půdotvorná role významných introdukovaných jehličnanů – douglasky tisolisté, jedle obrovské a borovice vejmutovky. Zprávy lesnického výzkumu, 53(1): 27-33.
29. Podrázský, V.; Remeš, J., 2009: Soil-forming effect of Grand fir (*Abies grandis* /Dougl. ex D.Don/Lindl.). Journal of forest science, 55(12): 533-539.
30. Požgaj, A.; Chovanec, D.; Kurjatko, S.; Babiak, M., 1997: Štruktúra a vlastnosti dreva. Bratislava: Príroda.
31. Rau, H. M.; König, A.; Ruetz, W.; Rumpf, H.; Schönfelder, E., 2008: Ergebnisse des westdeutschen IUFRO Küstentannen- Provenienzversuches im Alter 27: Beiträge aus der Nordwestdeutschen Forstlichen Versuchsanstalt, Band 4. Göttingen: Universitätsverlag Göttingen.
32. Riebel, H., 2007: Die Grosse Küstentanne [*Abies grandis* (Dougl. ex. D.Don.) Lindl.]:Holzeigenschaften und Holzverwendung. Forst und Holz, 62(6): 21-26.
33. Simpson, W.; TenWolde, A., 1999: Physical properties and moisture relations of wood. In: Wood handbook - Wood as an engineering material. Madison, US Department of Agriculture, Forest Service, pp. 3.1-3.24.
34. Šindelář, J.; Beran, F.; Frýdl, J.; Novotný, P., 2006: K možnostem lesnického využití některých cizokrajných druhů rodu *Abies* v ČR na základě hodnocení jejich růstu na lokalitě Jíloviště – Cukrák ve věku 30 let. Zprávy lesnického výzkumu, 51(4): 235-242.
35. Sonderegger, W.; Mandallaz, D.; Niemz, P., 2008: An investigation of the influence of selected factors on the properties of spruce wood. Wood Science and Technology, 42: 281-297 http://dx.doi.org/10.1007/s00226-007-0173-2.
36. Tauchman, P.; Hart, V.; Remeš, J., 2010: Srovnání produkce porostu douglasky tisolisté (*Pseudotsuga menziesii* / Mirbel/ Franco) s porostem smrku ztepilého (*Picea abies* L. Karst.) a stanovištně původním smíšeným porostem středního věku na území ŠLP v Kostelci nad Černými lesy. *Zprávy lesnického výzkumu*, 55(3): 187-194.
37. Vos, H.; Kharazipour, A., 2010: Eigenschaften von leichten, industriell hergestellten Spanplatten aus *Abies grandis* (Küstentanne). Forst und Holz, 65(1): 26-30.
38. Vytisková, M., 1973: Kvalita dřeva vejmutovky (*Pinus strobus* L.). Praha: SNTL.
39. Wagenführ, R., 2000: Holzatlas. Leipzig: Fachbuchverlag.
40. Wang, E.; Chen, T; Pang, S.; Karalus, A., 2008: Variation in anisotropic schrinkage of plantation-grown *Pinus radiata* wood. Moderas. Cienoia y techologia, 10(3): 243-249.
41. Yamashita, K.; Hirakawa, Y.; Nakatani, H.; Ikeda, M., 2009: Tangential and radial shrinkage variation within trees in sugi (*Cryptomeria japonica*) cultivars. J Wood Sci, 55: 161–168 http://dx.doi.org/10.1007/s10086-008-1012-2.

42. Ying, L.; Kretschman, D.E.; Bendtsen, B.A., 1994: Longitunidal schrinkage in fast-grown lobolly pine plantation wood. Forest product Journal, 44(1): 58-62.
43. Zobel, B.J.; Van Buitenen, J.P., 1989: Wood variation, its causes and control. Berlin: Springer-Verlag http://dx.doi.org/10.1007/978-3-642-74069-5.
44. *** ČSN 49 0101 (1980): Drevo – Všeobecné požiadavky na fyzikálne a mechanické skúšky.
45. *** ČSN 49 0108 (1993): Drevo – Zisťovanie hustoty.
46. *** ČSN 49 0128 (1989): Skúšky vlastností rastlého dreva – Metóda zisťovania zosýchavosti.
47. *** MZE 2010: Report on the forests state and forest management of the Czech Republic. Prague: Ministry of Agriculture.

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Determinants of Effects of Foreign Direct Investment in Terms of Slovak Republic and Wood-Processing Industry of Slovakia

Odrednice učinkovitosti izravnih stranih ulaganja u uvjetima poslovanja Republike Slovačke i slovačke drvoprerađivačke industrije

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ABSTRACT • *The presence of foreign direct investment in certain sectors or country determines several factors - the determinants of foreign direct investment. The article analyzes the selected factors of FDI inflows to the Slovak Republic and to the wood-processing industry in SR; it focuses primarily on assessing the contemporary situation of the business environment in Slovakia and investment incentives provided to foreign investors. The article also presents the development of foreign direct investment in Slovakia, in the branch of wood processing, analyzing the effects of FDI in specific conditions of the Slovak Republic and wood-processing industry.*

Key words: *foreign direct investment (FDI), effects of FDI, business environment, investment incentives, wood-processing branch*

SAŽETAK • *Zastupljenost izravnih stranih ulaganja (FDI) u pojedinim sektorima ili državi određen je s nekoliko čimbenika – čimbenika izravnih stranih ulaganja. U članku se analiziraju određeni čimbenici FDI-a u Slovačkoj Republici i u drvoprerađivačkoj industriji Slovačke, pri čemu se autori primarno fokusiraju na pristup trenutačnoj situaciji u poslovnom okruženju u Slovačkoj i na ulagačke poticaje koje strani ulagači imaju. Članak također predočuje razvoj izravnih stranih ulaganja u Slovačku, u drvoprerađivačku djelatnost, analizirajući učinke FDI-a u specifičnim uvjetima u kojima se prerada drva u Slovačkoj nalazi.*

Ključne riječi*: izravna strana ulaganja (FDI), učinci FDI, poslovno okruženje, ulagački poticaji, drvoprerađivačka djelatnost*

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1 INTRODUCTION
1. UVOD

The inflow of foreign direct investments (FDI) into the country affects a number of factors described in literature or published annually for example in UNCTAD surveys. Major factors in terms of savings are low labor costs, availability of resources (material, energy, financial). On the other hand, factors that influence revenues are usually market size and market growth (*World Investment Prospect Survey, 2009*). However, it is also important to evaluate factors that affect the business environment and the presence of foreign investors in the country. These factors are condition and quality of business environment, the level of corruption, but also the rate of assistance from the state - investment incentives (Ferenčíková *et al*, 2010).

The results of analysis of rating institutions show that the attractiveness of some country for foreign direct investment is crucially dependent on favorable business environment, the quality of institutional environment, as well as the relative price and cost competitiveness (Drábek and Polách, 2008). However, the dynamics of FDI flow is significantly influenced by the targeted state policy to promote foreign investments (Drábek and Jelačić, 2007). Results of the global economic crisis, as well as the acceptance of a comprehensive system of measures to reduce them, may affect not only the long-term macroeconomic stability, but also the policy towards FDI, and hence foreign direct investment inflows to Slovakia both in the short and long term.

It can be concluded that maintaining long-term political stability in Slovakia is also reflected positively on the real economy, which is impacted in the continuity of macroeconomic stability and keeping up the suitable business environment. The evaluation of the International Monetary Fund (*IMF, 2009*) shows that long term positive economic development in the SR is manifested in the rapid GDP growth, which was based on health macroeconomic and structural policies and helped to speed up the convergence process of the Slovak economy. Since the Slovak economy is an open and export-oriented economy, its development is significantly influenced by development in the external economic environment. This is confirmed by time-coordinated course of the economic crisis in the external environment and in Slovakia, which also shows that the Slovak economy is tightly integrated into European and world economy (Okáli *et al*, 2009). Simultaneously, the imported recession also causes many negative consequences on the domestic economy. Such close connection with the external environment is also reflected in forecasts of economic development for the years 2012-2015, which can be evaluated as positive in comparison with other EU countries.

The government deficit exceeding 3 % of GDP is not the cause for investors concerns in the current situation. However, the expected economic recovery will be reflected in the re-tightening of the fiscal policy, and it will be a positive signal to encourage the investor confidence, underlining the government's responsible approach to meeting the commitments under the Stability and Growth Pact (SGP).

The main objective of each company is an efficient and successful business. There is a general economic principle: to achieve the maximum result with the minimum of means (Oblak *et al*, 2008, Stasiak-Betlejewska *et al*, 2007). The objective of this research was to evaluate the impact of investment and foreign direct investment in the Slovak Republic with the focus on the wood-processing industry in SR all based on the analysis of time series of selected economic indicators, business and investment environment and investment incentives.

To achieve this objective partial objectives were formulated:

– the analysis of foreign direct investment in the Slovak Republic as well as in individual sectors of the wood-processing industry, analysis of the business and investment environment, investment incentives in Slovakia,
– the evaluation of selected economic indicators in SR and wood-processing industry of SR with the application of selected statistical methods (correlation and regression analysis), the interpretation of the solution and obtained results.

2 METHODOLOGY OF RESEARCH
2. METODA ISTRAŽIVANJA

Statistical methods were used to analyze and evaluate the effects of investment in SR and in wood-processing industry of SR. Correlation analysis describes the relationship between two quantitative variables. This analysis does not imply cause and effect relationship between two variables. Linear regression allows to examine the cause and the subsequent relationship between two variables x and y. The regression line determines the dependence. The chart of correlation and linear regression analysis shows the values of independent and dependent variables in each year and the regression line. Values closer to the regression line mean stronger impact on the examined variable.

Correlation and regression analysis of research focuses on foreign direct investment in Slovakia, the GDP growth of Slovakia, investment and selected variables in the wood-processing branch. These are indicators that characterize the economic situation in the mentioned sector, focusing on indicators that have a positive impact on the economic development of the wood-processing industry.

The selected economic indicators are evaluated over a period of 10 years in the 1999-2008 time series. Software products STATISTICA 9 of the company StatSoft and the application Excel from Microsoft Office 2003 from Microsoft, as well as spreadsheet and graphics tools of applications were used for data processing.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Business environment in Slovakia
3.1. Poslovno okruženje u Slovačkoj

Generally, it can be stated that the business environment in Slovakia is not quite good. According to the

Table 1 Index of Economic Freedom worldwide in 2010
Tablica 1. Indeks ekonomske slobode u svijetu u 2010. godini

World Rank *Mjesto u svijetu*	**Overall Index** *Ukupni indeks*	**Country** *Država*	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
1.	89,7	Hong Kong	98.7	90.0	93.0	93.7	83.1	90.0	90.0	90.0	81.0	87.4
2.	86,1	Singapore	98.2	90.0	90.7	95.3	80.9	75.0	50.0	90.0	92.0	98.9
3.	82,6	Australia	90.3	85.1	61.4	64.9	82.7	80.0	90.0	90.0	87.0	94.0
4.	82,1	New Zealand	99.9	86.0	63.6	51.3	83.1	80.0	80.0	95.0	93.0	88.8
5.	81,3	Ireland	92.8	87.5	71.1	61.8	79.0	95.0	80.0	90.0	77.0	79.0
6.	81,1	Switzerland	81.2	90.0	68.2	68.9	81.3	80.0	80.0	90.0	90.0	81.8
7.	80,4	Canada	96.5	88.1	76.7	54.1	75.4	75.0	80.0	90.0	87.0	81.5
8.	78,0	United States	91.3	86.9	67.5	58.0	78.0	75.0	70.0	85.0	73.0	94.8
9.	77,9	Denmark	97.9	87.5	35.9	22.0	79.3	90.0	90.0	90.0	96.0	93.7
10.	77,2	Chile	64.8	88.0	77.5	89.6	73.0	80.0	70.0	85.0	69.0	75.4
34.	69,8	Czech Republic	65.5	87.5	80.1	45.6	75.6	70.0	80.0	65.0	52.0	76.4
35.	69,7	Slovak Republic	72.6	87.5	84.0	64.5	78.2	70.0	70.0	55.0	50.0	65.0
51.	66,1	Hungary	76.8	87.5	68.6	25.9	74.1	75.0	70.0	65.0	51.0	67.6
71.	63,2	Poland	62.2	87.5	74.9	46.8	78.1	60.0	60.0	55.0	46.0	61.5
177.	26,7	Cuba										
178.	21,4	Zimbabwe										
179.	1,0	North Korea										

Scale 0-100, 100 – maximum freedom, Source: data from heritage.org/Index
Skala 0-100, 100 – maksimalna sloboda; Izvor: podaci s heritage.org/Index

Slovak Chamber of Commerce and Industry (SCCI), it is getting gradually worse. The survey of SCCI shows that 71 % of the 170 surveyed companies consider the business environment as adverse. Only 2 % of surveyed companies identified the Slovak business environment as favorable. Based on the survey, it follows that 59 % of surveyed companies expect no change in the business environment. Only 6 % of respondents expect improving of the business environment and 35 % its further deterioration.

Slovakia had its economic growth based on the quality of business environment, of course using the comparative advantages which the country still has, but their strength in relation to other countries gradually weakens (Merková and Drábek, 2010). Justice and legislation are among the worst areas of business environment in Slovakia. Worse legislative environment according to the SCCI survey is particularly evident in the rapid adoption of amendments and laws (Merková, 2010).

The situation of the business environment in Slovakia and other countries was analyzed on the basis of five ratings - indexes and rankings compiled by various world expert organizations and institutions. Ratings are not only supported by statistical data of the economic development of countries; they are the result of experts' opinions and independent assessors' perceptions of the development of each country in comparison with the development in other economies. Although rankings are not scientific facts, the mentioned institutions that compiled the rankings are considered as independent, objective and credible. The ratings reflect the perceptions of the situation in the country from the perspective of the business sector.

3.1.1 Index of Economic Freedom
3.1.1. Indeks ekonomske slobode

According to the *Index of Economic Freedom*[1] in 2010, Slovakia improved by 0.3 points and was ranked 35th with the overall assessment of 69.7 points (in 2009 it was 69.4 points, 36th place). The overall score is higher than the world average. The Czech Republic took the highest position among V4 countries after five years, and was ranked 34th (37th in 2009). Hungary was ranked 51st (44th in 2009) and Poland 71st (82nd step in 2009). However, Poland is included among top ten countries with the best annual improvement in the ranking. According to the European region, Slovakia ranked 18th out of 43 countries (in 2009 it was ranked 20th). The former British colony of Hong Kong has been declared the freest economy in the world for 16 times.

The Index of Economic Freedom contains ten subcriteria:

[1] Business Freedom
[2] Trade Freedom
[3] Fiscal Freedom
[4] Government Spending
[5] Monetary Freedom
[6] Investment Freedom
[7] Financial Freedom
[8] Property Rights
[9] Freedom from Corruption
[10] Labor Freedom

Experts in evaluation of Slovakia show a significant deterioration in the category of freedom in the labor market, but offset by improvements in other areas. Slovakia is still limited by two institutional weaknesses - the judicial system is inefficient and slow, and in recent years efforts to eliminate the corruption have

[1] *Economic Freedom Score* is compiled and published by the Heritage Foundation, Washington No.1 think tank and the Wall Street Journal, the index covers 183 countries.

Table 2 Index of Economic Freedom in V4 countries in the period 2008-2010
Tablica 2. Indeks ekonomske slobode za zemlje Višegradske skupine V4 u razdoblju 2008 -2010.

Country *Država*	**Rank in 2010** *Mjesto u svijetu u 2010.*	**Rank in 2009** *Mjesto u svijetu u 2009.*	**Rank in 2008** *Mjesto u svijetu u 2008.*
Czech Republic	34.	37.	37.
Slovak Republic	**35.**	**36.**	**35.**
Hungary	51.	44.	43.
Poland	71.	82.	83.

Source: data from heritage.org/Index / *Izvor: podaci s heritage.org/ Index*

shown only limited progress; in the long-term perspective, investors consider these weaknesses to be a serious factor in locating the foreign enterprises.

3.1.2 Ease of Doing Business
3.1.2. Lakoća poslovanja

In the *Ease of Doing Business*[2] Slovakia was ranked worse in 2010 than in previous years. Among all countries, Slovakia fell from 32nd place in 2008 to 35th in 2009 and 42nd in 2010. Although Slovakia has maintained its leading position among the V4 countries (Czech Republic is 74th, Hungary 47th and Poland 72nd), Slovakia is lagging behind faster reformers of Eastern Europe such as Georgia, Estonia, Latvia and Lithuania. Despite this, however, Slovakia overtook five industrially more developed economies of Europe (Portugal 48th, Spain 62nd, Luxembourg 64th, Italy 78th, Greece 109th). Unexpectedly, Slovakia as the largest manufacturer of automobiles per capita in the world, belongs to the countries in the EU with the lowest "trading across borders". The Slovak government needs to reduce requirements and shorten the time required for exports and imports, and to optimize this process through competitiveness and transparency.

Slovakia can support the entrepreneurial spirit by simplifying the procedures for starting business and by providing steps aimed at simplifying business registration and making it more acceptable for enterprises. In addition, the report of Doing Business indicates that Slovakia needs to shorten the time needed for the enforcement of contracts and decrease costs associated with enforcement. Slovakia has one of the longest waiting times among European countries for obtaining a building permit (287 days), followed only by Poland (308 days) and Cyprus (677 days). This is especially troubling when compared with countries such as Finland or Denmark, where the same may be carried out in 38 or 69 days according to the World Bank.

Slovakia has a poor rating in the category of closing the business, particularly in two areas: the duration of the bankruptcy settlement - about 4 years (followed only by the Czech Republic with a period of 6.5 years) and bankruptcy costs as a percentage of assets, which is 18 % in Slovakia as well as in Austria (followed by Poland with only 20 % and Italy with 22 %). Slovakia has a better score than most EU countries in the cost of obtaining a building permit (the second lowest in the EU, 13.8 multiple of the average wage). Building permits in Hungary is 9.8 times higher than the average wage, while in Bulgaria it is an overwhelming factor - 436.5 times more than the average wage. Investors may obtain a building permit in Slovakia completing 13 treatments, which is less than most other EU countries require (*Report on the state of business environment in SR, Ministry of Economy, 2010*).

What makes Slovakia particularly attractive is the process of acquiring ownership. Slovakia is the country with the lowest costs for this process, which is very fast and efficient. Slovakia is among the top six countries in the strength of their legal rights in obtaining the loan. This index measures the protection rules in relation to

[2] *Ease of Doing Business* – data compiled by the World Bank and International Finance Corporation in the report Doing Business, giving analysis of 183 countries. Annual report 2010 covers data in the period June 2008 to May 2009.
Source of data: http://www.doingbusiness.org

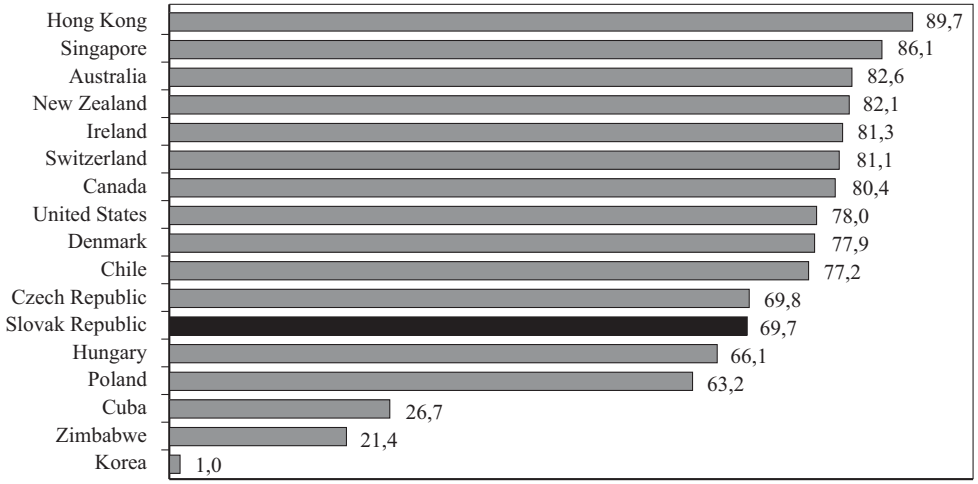

Figure 1 Index of Economic Freedom in 2010 (Source: data from heritage.org/Index)
Slika 1. Indeks ekonomske slobode u 2010. godini (izvor: podaci s heritage.org/Index)

Table 3 Ease of Doing Business worldwide in 2010
Tablica 3. Lakoća poslovanja u svijetu za 2010. godinu

World Rank *Mjesto u svijetu*	**Country** *Država*	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
1.	Singapore	4	2	1	16	4	2	5	1	13	2
2.	New Zealand	1	5	15	3	4	1	9	26	10	17
3.	Hong Kong, China	18	1	6	75	4	3	3	2	3	13
4.	United States	8	25	1	12	4	5	61	18	8	15
5.	United Kingdom	16	16	35	23	2	10	16	16	23	9
6.	Denmark	28	10	9	47	15	27	13	6	28	7
7.	Ireland	9	30	27	79	15	5	6	21	37	6
8.	Canada	2	29	17	35	30	5	28	38	58	4
9.	Australia	3	62	1	34	4	57	47	27	16	14
10.	Norway	35	65	114	8	43	20	17	9	4	3
42.	Slovak Republic	66	56	81	11	15	109	119	113	61	39
47.	Hungary	39	87	77	61	30	119	122	70	14	58
72.	Poland	117	163	76	88	15	41	151	42	75	85
74.	Czech Republic	113	76	25	62	43	93	121	53	82	116
181.	Guinea-Bissau										
182.	Congo, Dem. Rep.										
183.	Central African Republic										

Source: data of Doing Business / *Izvor: podaci s Doing Businessa*

Table 4 Ranking of V4 countries in global ranking of Doing Business in the period 2006-2010
Tablica 4. Mjesto zemalja V4 u globalnom redoslijedu Doing businessa za razdoblje 2006 – 2010.

Country *Država*	**Report 2010** *Izvješće za 2010.*	**Report 2009** *Izvješće za 2009.*	**Report 2008** *Izvješće za 2008.*	**Report 2007** *Izvješće za 2007.*	**Report 2006** *Izvješće za 2006.*
Slovak Republic	42.	35.	32.	36.	34.
Czech Republic	74.	66.	56.	52.	50.
Hungary	47.	41.	45.	66.	60.
Poland	72.	72.	74.	75.	74.

Source: data from Doing Business / *Izvor: podaci s Doing Businessa*

the possession of movable property. However, Slovakia was ranked between 18th and 23rd place in terms of quality and availability of debt information obtained from public and private debt registries *(rokovania.sk)*. In EU Slovakia is ranked between the 7th and 10th place according to the employment index, which evaluates the rules for hiring people, working time, number of leave days and statutory requirements for dismissal of employees for economic reasons (*spectator.sk*).

The Ease of Doing Business consists of ten indicators:

[1] Starting a Business
[2] Dealing with Construction Permits
[3] Employing Workers
[4] Registering Property
[5] Getting Credit
[6] Protecting Investors
[7] Paying Taxes
[8] Trading Across Borders
[9] Enforcing Contracts
[10] Closing a Business

3.1.3 Global Competitiveness Index
3.1.3. Indeks globalne kompetitivnosti

According to the *Global Competitiveness Index*[3] Slovakia was ranked in the group of developed countries in 2009 for the first time (based on last year's GDP level); the economic development of these countries is mainly based on the ability to innovate.

The Index consists of 12 pillars of competitiveness:

[1] Institutions
[2] Infrastructure
[3] Macroeconomic environment
[4] Health and primary education
[5] Higher education and training
[6] Goods market efficiency
[7] Labor market efficiency
[8] Financial market development
[9] Technological readiness
[10] Market size
[11] Business sophistication
[12] Innovation

Slovakia was gradually decreasing from the 36th place in 2006 to 37th, 41st, 46th and finally 47th place in 2010. The Czech Republic annually rose by 2 positions, Poland's position improved by 7 places and Hungary also moved upward. Slovakia is, thus, the only country from the V4 group, rating decreases.

According to the Executive Director of the Business Alliance of Slovakia, which is a partner institution of the World Economic Forum, the global economic crisis means that most countries assessed lower competitiveness index score this year. However, due to the strong

[3] *Global Competitiveness Index* compiled by the World Economic Forum annually in the Global Competitiveness Report, covers 133 countries. *Source of data: http://www.weforum.org/documents/GCR09/index.html*

Table 5 Global Competitiveness Index worldwide in 2010
Tablica 5. Indeks globalne kompetitivnosti u svijetu za 2010. godinu

Rank *Mjesto u svijetu*	**Country** / *Država*	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
1.	Switzerland	8	5	17	21	6	5	2	14	3	36	3	2
2.	United States	34	8	93	36	7	12	3	20	13	1	5	1
3.	Singapore	1	4	35	13	5	1	1	2	6	39	14	8
4.	Sweden	2	14	15	12	3	4	19	12	1	32	4	5
5.	Denmark	3	12	14	6	2	7	5	8	4	49	8	10
6.	Finland	4	10	12	1	1	19	23	7	10	53	9	3
7.	Germany	16	1	30	24	22	18	70	36	12	5	2	7
8.	Japan	28	13	97	19	23	17	12	40	255	3	1	4
9.	Canada	17	7	31	7	9	16	7	11	11	14	17	12
10.	Netherlands	10	15	38	14	10	6	27	23	2	18	6	13
31.	Czech Republic	62	48	43	33	24	27	20	42	30	40	25	25
46.	Poland	66	103	74	35	27	53	50	44	48	20	44	52
47.	Slovak Republic	78	63	40	48	47	32	29	28	33	57	51	68
58.	Hungary	76	57	83	53	35	64	63	69	40	45	76	45
131.	Chad												
132.	Zimbabwe												
133.	Burundi												

Source: data of Global Competitiveness Report / *Izvor: podaci s Global Competitiveness Reporta*

Table 6 Global Competitiveness Index in V4 countries in the period 2006-2010
Tablica 6. Indeks globalne kompetitivnosti za zemlje V4 za razdoblje 2006 - 2010.

Country / *Država*	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006
Czech Republic	31.	33.	33.	29.	29.
Poland	46.	53.	51.	48.	43.
Slovak Republic	47.	46.	41.	37.	36.
Hungary	58.	62.	47.	41.	35.

Source: data of Global Competitiveness Report / *Izvor: podaci s Global Competitiveness Reporta*

interdependence of economies, there was no pronounced movement in the ranking. Regarding the ranking of Slovakia he says: "Poor government's ability to improve the business environment, reform and eliminate the major barriers of business were the cause for Slovakia to fall in the ranking for the third time in a raw." (*alianciapas.sk*). The basic disadvantage of Slovakia is that most foreign companies have their innovative potential organized in the home country, so the share of R&D capacities is gradually reduced, and thus it fails to engage the capacities into innovative projects.

3.1.4 Global Competitiveness Breakdown
3.1.4. Smanjenje globalne kompetitivnosti

According to Global *Competitiveness Breakdown*[4] Slovakia results in 33rd position in year 2010, occupies second position among V4 countries in long-term situation. The Global Competitiveness Breakdown is compiled on the base of four indicators as economic performance, government efficiency, business efficiency and infrastructure. Each one consists from next five subcriteria.

[4] *Global Competitiveness Breakdown* compiled by the Swiss Institute of the International Institute for Management Development in the annual report the World Competitiveness Yearbook, covers 57 countries worldwide. *Source of data: http://www.worldcompetitiveness.com*

3.1.5 Corruption Perceptions Index
3.1.5. Indeks percepcije koruptivnosti

In 2009 Slovakia became one of the 9 countries with the worst decline in scores. According to the Corruption Perceptions Index, Slovakia set back four years ago. According to the *Corruption Perceptions Index*[5] in 2009, the score of Slovakia dropped the most in the history of measurements since 1998, from the level of 5.0 to 4.5. Slovakia also worsened annually in the countries ranking: it dropped from the 52nd-53rd to the 56th-60th place. For the first time since 2001 Slovakia is ranked worst of the V4 countries (*Transparency International*).

Finally, in connection with the presented ratings, it should be noted that the evaluation does not always reflect the real and actual situation of the country's economy. Can the Index of Economic Freedom be considered as objective, if in 2010 Ireland was ranked 5th, and in

[5] *Corruption Perceptions Index* is compiled by the Transparency International, covers 180 countries worldwide. A composite index, the CPI is based on 13 different expert and business surveys. Eight surveys are made for Slovakia every year. Transparency International makes neither of them, and they are made by different institutions. For Slovakia, the last time they were as follows: the World Economic Forum, Freedom House, The Economist Intelligence Unit, International Institute for Management Development, IHS Global Insight and Bertelsmann Foundation.*Source of data: http://www.transparency.sk/vystupy/rebricky/*

Table 7 Global Competitiveness Breakdown worldwide in 2010
Tablica 7. Smanjenje globalne kompetitivnosti u svijetu za 2010. godinu

Rank *Mjesto*	**Country** *Država*	**Economic Performance** *Ekonomski rezultati*	**Government Efficiency** *Učinkovitost vlade*	**Business Efficiency** *Učinkovitost poslovanja*	**Infrastructure** *Infrastruktura*
1.	United Nations	1	20	16	1
2.	Hong Kong	3	2	1	19
3.	Singapore	8	1	4	8
4.	Switzerland	13	3	3	4
5.	Denmark	23	4	2	6
6.	Sweden	20	10	6	2
7.	Australia	15	8	7	12
8.	Canada	16	9	9	7
9.	Finland	40	6	5	3
10.	Netherland	7	14	8	11
29.	Czech Republic	25	31	36	25
33.	Slovak Republic	34	34	26	37
44.	Poland	39	44	50	39
45.	Hungary	33	50	52	33
57.	Venezuela				

Source: data of the World Competitiveness Yearbook / *Izvor: podaci iz World Competitiveness Yearbooka*

Table 8 Global Competitiveness Breakdown in V4 countries in the period 2006-2010
Tablica 8. Smanjenje globalne kompetitivnosti za zemlje V4 u razdoblju 2006 - 2010.

Country / *Država*	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006
Czech Republic	29.	28.	32.	28.	30.
Slovak Republic	33.	30.	34.	33.	34.
Poland	44.	44.	52.	50.	48.
Hungary	45.	38.	35.	35.	31.

Source: data of the World Competitiveness Yearbook / *Izvor: podaci iz World Competitiveness Yearbooka*

Table 9 Corruption Perceptions Index worldwide in 2009
Tablica 9. Indeks percepcije koruptivnosti u svijetu za 2009

Rank *Mjesto*	**Country** *Država*	**Corruption Perceptions Index 2009** *Indeks percepcije koruptivnosti za 2009.*
1.	New Zealand	9.4
2.	Denmark	9.3
3.	Singapore	9.2
3.	Sweden	9.2
5.	Switzerland	9.0
6. – 7.	Finland	8.9
6. – 7.	Nederland	8.9
8. – 10.	Australia	8.7
8. – 10.	Canada	8.7
8. – 10.	Iceland	8.7
46.	Hungary	5.1
49.	Poland	5.0
52.	Czech Republic	4.9
56.	Slovak Republic	4.5
178.	Myanmar	1.4
179.	Afghanistan	1.3
180.	Somalia	1.1

Scale: 0-10, 10 being the best, Source: Transparency International data
Skala: 0-10; 10 je najbolj;, izvor: podaci Transparency Internationala

2009 it nearly declared the state bankruptcy due to extreme indebtedness? Can this country be considered economically free in these conditions? The same applies to the USA (8th place). Can its Quality of Business Environment be assessed as reliable, if the best ranked countries are those most indebted in the world such as the USA (4th place), Great Britain (5th place) and the abovementioned Ireland (7th place)? Even less credible are the results of the Global Competitiveness Index. According to this indicator the USA are excellent (2nd place), and the objectively the most competitive China is ranked 29th place. However, experts' rankings are accepted by investors, of course in terms of their insights into this issue (Drábek and Merková, 2010).

3.2 Investment incentives for the development of investing
3.2. Ulagački poticaji za razvoj investiranja

The analyzed data show that Slovakia still has significant comparative advantages (high correlation between wage and labor productivity, low cost of release, index of rights of creditors and debtors, a healthy banking sector, relatively good availability of financing by loans, low duty barriers, support of the FDI, good conditions for technology transfer and FDI), which should be used, while the negative factors that foreign investors analyze with the location of their business activities should be removed (Merková and

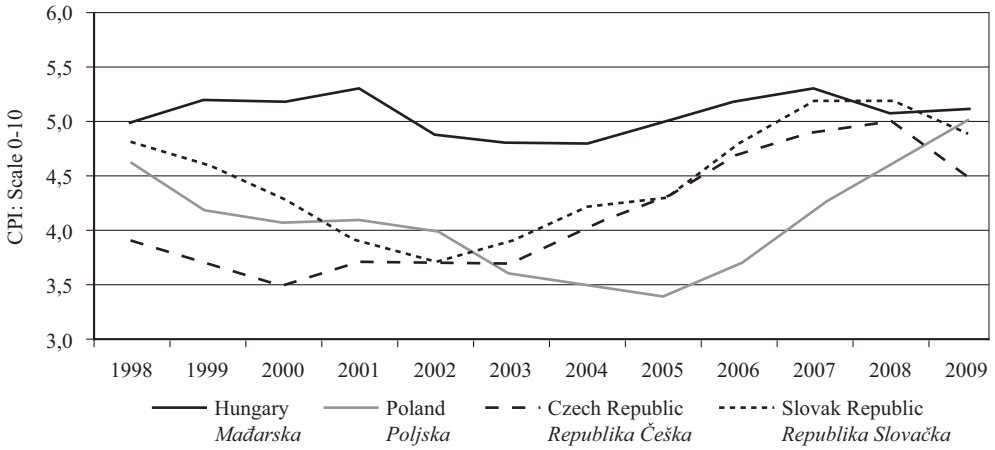

Figure 2 Corruption Perceptions Index in V4 countries in the period 1998-2009 (Scale: 0-10, 10 being the best, Source: Transparency International data)
Slika 2. Indeks percepcije koruptivnosti u zemljama V4 za razdoblje 1998 - 2009. (Skala: 0-10; 10 je najbolje; izvor: podaci Transparency Internationala)

Table 10 Corruption Perceptions Index in V4 countries in the period 1998-2009
Tablica 10. Indeks percepcije koruptivnosti u zemljama V4 za razdoblje 1998 - 2009.

Country / *Država*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Hungary	5.0	5.2	5.2	5.3	4.9	4.8	4.8	5.0	5.2	5.3	5.1	5.1
Poland	4.6	4.2	4.1	4.1	4.0	3.6	3.5	3.4	3.7	4.2	4.6	5.0
Czech Republic	4.8	4.6	4.3	3.9	3.7	3.9	4.2	4.3	4.8	5.2	5.2	4.9
Slovak Republic	3.9	3.7	3.5	3.7	3.7	3.7	4.0	4.3	4.7	4.9	5.0	4.5

Drábek, 2011). In connection with the FDI inflow and encouragement of foreign companies to invest, it is necessary to present the investment incentives - all the measurable economic benefits provided by the host government to foreign investors for the purpose of motivation in business activities. The primary role of the investment incentives should be to motivate the investors to place their new projects in the so called disadvantages areas, which means in the regions with higher unemployment, lower infrastructure quality, etc. The positive impact of a new investment shall be proved by job creation, by chances for the graduates to be used as well as by creation of new entrepreneurial opportunities for local companies (*Ministry of Economy, 2010*).

Investment aid is a form of state aid targeted at promoting economic development of the most disadvantaged regions and at mitigating regional disparities. Granting of investment should stimulate the creation of new jobs.

Investment aid beneficiary can be a legal person or a natural person–entrepreneur with a registered office in the Slovak Republic, incorporated in the Commercial Register or the Trade License Register, ready to implement an investment plan in the Slovak Republic; the beneficiary must be 100 % owned by the applicant, or the applicant must be a controlling person of the beneficiary. The beneficiaries' investment activities and projects have to be in compliance with the Act 565/2007 Coll. the "Act on Investment Aid".

One of the factors affecting the investor's decision on its investment placement is also the amount and the structure of the investment incentives that may be obtained. The so-called intensity of the aid means the maximum proportion of the eligible costs that may be approved for the investor in the form of particular investment incentives. The maximum intensity differs depending on the district. The limit in Bratislava region is 0 %, Western Slovakia 20-40 %, Central Slovakia 25-50 % and Eastern Slovakia 25-50 % (*Ministry of Economy, 2010*).

The Act on Investment Aid 565/2007 Coll. divides the projects that may be supported into four categories:

– Industrial production
– Technological centers
– Shared services centers
– Tourism

The main factors affecting the acquisition of investment aid are (*Ministry of Foreign Affairs, 2009*):

– Amount of investment
– Region in which the project will be implemented
– Unemployment rate in the region
– Number of direct and indirect jobs created
– Intensity of state aid in the region
– Technological standard, innovation
– Amount of training costs
– Share of highly qualified staff
– Environmental impact
– Quality of the investment plan and application completeness.

If the investor meets all the requirements of the investment aid in individual areas, it can apply for the following forms of investment incentives (*Slovak Investment and Trade Development Agency, SARIO*):

a) subsidy for the acquisition of material assets and immaterial assets,
b) an income tax relief,

Table 11 Forms of investment incentives
Tablica 11. Oblici poticaja investicijama

Forms of investment incentives in the Slovak Republic *Oblici poticaja investicijama u Slovačkoj Republici*	
Direct support for: *Izravna potpora za:*	**Indirect support for:** *Neizravna potpora za:*
construction / *izgradnju* technology / *tehnologije* research and development / *istraživanje i razvoj* job creation, retraining of the workforce / *nova radna mjesta, izobrazbu kadrova* allowance for staff training / *pozajmice za obuku kadrova* land acquisition and implementation of infrastructure / *kupnju zemljišta i uvođenje infrastrukture* loan policy, lower interest, longer repayment period, the state guarantee / *zajmove s nižom kamatom, duljim rokovima povrata, državna jamstva*	income tax relief / *oslobađanje od poreza na dohodak* transfer of real estate or exchange of real estate for the price lower than the general value / *prijenos nekretnina ili za iznajmljivanje nekretnina za manji iznos od uobičajenoga* providing advisory services free of charge or for a partial payment or deferred tax payment / *davanje savjetodavnih usluga bez naknade, za djelomično plaćanje ili za plaćanje pojedinih poreznih davanja*

Source: data of the Ministry of Economy in SR / *Izvor: podaci Ministarstva gospodarstva Slovačke*

Table 12 Overview of investment aid in Slovakia in the period 2002-2010 (mill. EUR)
Tablica 12. Pregled potpora investicijama u Slovačkoj u razdoblju 2002 - 2010. (mil. EUR)

Forms of investment aid in Slovakia in the period 2002-2010 *Oblici potpore investicijama u Slovačkoj u razdoblju 2002 - 2010.*	**Approved** *Odobreno*	**Used** *Iskorišteno*
Subsidy for the acquisition of longterm assets / *Potpora za stjecanje dugotrajne imovine*	547.50	393.60
Contribution for new job creation / *Potpora za kreiranje novih radnih mjesta*	92.70	48.11
Contribution for staff retraining / *Potpora za obuku kadrova*	52.51	42.68
Income tax relief /*Oslobođenje od poreza na dohodak*	439.39	90.06
Transfer or exchange of real estate / *Prijenos ili promjena nekretnina*	46.69	46.69
Overall / *Ukupno*	1178.79	621.16

Source: data of the Ministry of Economy in SR / *Izvor: podaci Ministarstva gospodarstva Slovačke*

c) contribution for new jobs created,
d) transfer of immovable property or exchange of immovable property at a price lower than a general asset value.

Investment incentives mean the price or cost that the country must cover to some extent in connection with the inflow of foreign capital (in periods of deficit in domestic financial resources) considering the positive effects that FDI will bring (in the past it was the solution of two serious problems in the SR - employment growth, improved trade balance) (Drábek and Merková, 2010).

3.3 Foreign direct investment flows in the SR and WPI SR
3.3. Izravna strana ulaganja u Slovačku i u slovačku preradu drva

Data of the United Nation Conference for Trade and Development (UNCTAD) held in 2008 show that Slovakia was most highly ranked among 27 EU countries according to the indicator of FDI inflows per capita – 16th place with the value of 632 USD/capita. The evaluation of the total FDI inflows in millions of USD, as well as the percentage of FDI in GDP of the country (17th place) show similar results.

At the beginning of transformation, Slovakia had similar comparative advantages as other countries in Central and Eastern Europe, particularly qualified and cheap labor, cheap raw material and energy inputs, good location and close relations with the EU. Until 2000, FDI inflows had risen, but its volume lagged behind the volume of FDI inflows in the other V4 countries (*The concept of management of FDI, Ministry of Economy, 2009*).

FDI inflows into the wood-processing industry (WPI) in the presented period of 5 years reached the largest volume in 2005, amounting to 1.557 billion SKK, and however 90 % of these resources was absorbed by the furniture industry. In other years, less than half of this value was achieved. The second largest inflow was in 2006, when 835 million SKK were invested into WPI. Pulp and paper industry dominated in 2006 and 2007 with the inflows of 608 million SKK and 606 million SKK of FDI, respectively.

The smallest amount of foreign investment flowed into the sector of wood industry (annually and totally) with the exception of 2004, when the wood industry recorded FDI inflows of 556 million EUR. The opposite trend was recorded in the industrial production of the Slovak Republic, with the lowest FDI inflows, amounting to 10.901 billion EUR, in 2005.

Stagnation of investment in sawmilling, construction and carpentry was reported in the period 1999-2002, and in the period 2003-2006 an increase was recorded amounting to nearly 1.7 to 2.6 billion Slovak crowns (SKK) per year (*NLC, 2009*). A significant increase of investment to the level of 6.07 billion SKK occurred in 2007, but this growth was followed by a drop to the level of 2.25 billion SKK.

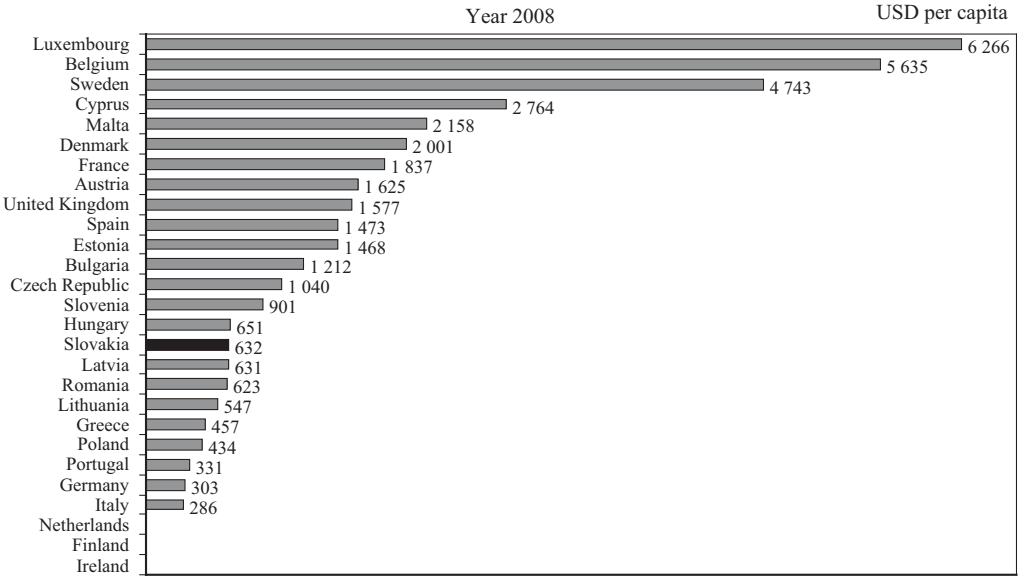

Figure 3 Foreign direct investment inflows per capita in the EU countries, USD per capita. (Source: Eurostat data, http://epp.eurostat.ec.europa.eu).
Slika 3. Izravna strana ulaganja po stanovniku zemalja EU, USD po stanovniku. (Izvor: podaci Eurostata, http://epp.eurostat.ec.europa.eu).

Table 13 Investment in the WPI and industrial production of the Slovak Republic (mill. SKK)
Tablica 13. Investicije u WPI i industrijsku proizvodnju Slovačke Republike (u mil. SKK)

Indicator *Pokazatelj*	Sector / Sektor	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Investment (millions SKK) / *Investicije (u mil. SKK*)	Wood Industry (WI) / *Prerada drva (WI)*	506	881	766	734	1 788	1 710	2 564	2 573	6 068	2 249
	Furniture Industry (FI) / *Proizvodnja namještaja (FI)*	580	1 572	1 645	701	794	1 687	2 024	2 787	4 512	1 644
	Pulp and paper Industry (PPI) / *Proizvodnja pulpe i papira (PPI)*	4 785	1 594	2 205	3 083	6 634	5 161	4 744	3 185	2 796	3 300
	Wood Processing Industry (WPI) / *Drvoprerađivačka industrija (WPI)*	5 871	4 048	4 616	4 519	9 216	8 558	9 331	8 545	13 375	7 194
	Industrial production / *Industrijska proizvodnja*	44 489	42 328	71 077	56 466	59 152	71 897	104 046	105 101	102 993	98 627

Source: data from Ministry of Economy SR and Statistical Office of SR
Izvor: podaci Ministarstva gospodarstva Slovačke i Statističkog ureda Slovačke

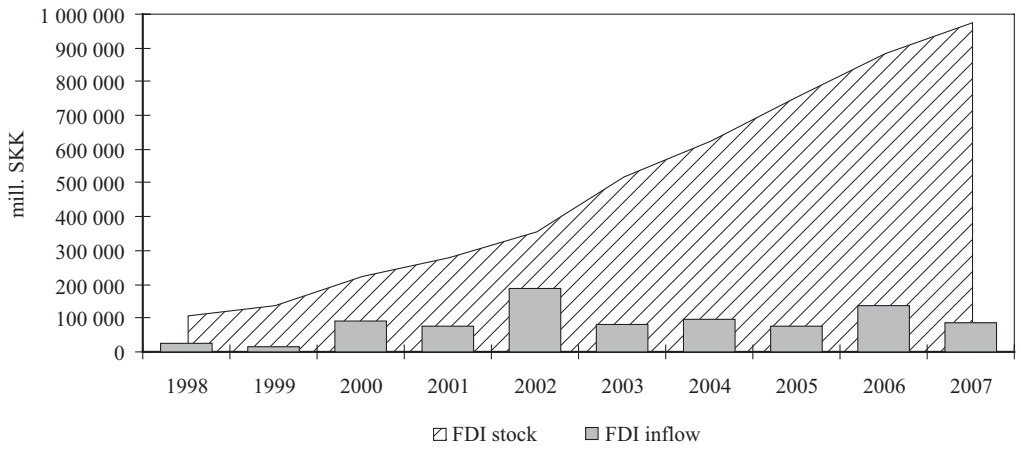

Figure 4 Foreign direct investments in the Slovak Republic, mill. SKK. (Source: NBS data, National Bank of Slovakia.)
Slika 4. Izravna strana ulaganja u Slovačku, u mil. SKK. (Izvor: podaci NBS-a, National Bank of Slovakia.)

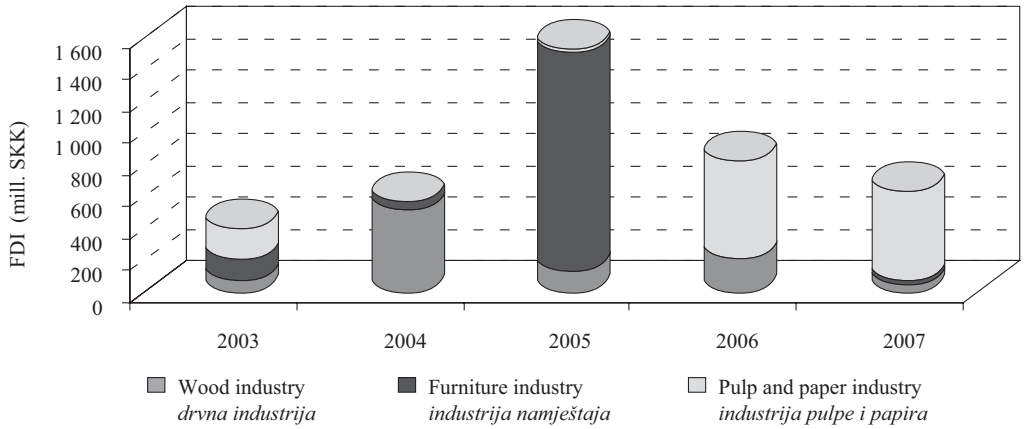

Figure 5 Inflow of FDI in sectors of wood-processing industry (mill. SKK)
Source: NBS data
Slika 5. FDI u sektor drvoprerađivačke industrije (u mil. SKK)
Izvor: podaci NBS-a

The sector of furniture production has seen better investment in the years 2000, 2001, 2004-2006 and this fact caused the growth of labor productivity. The investment was in the range of 1.5 to 2.8 billion SKK in the years mentioned above. Similarly as in the sector of wood industry (WI), in furniture industry (FI) an equally sharp increase was recorded in 2006-2008, from 2.8 billion SKK to 4.5 billion SKK in 2007 and then a fall to 1.6 billion SKK in 2008.

Rapid changes of investment in the pulp and paper industry (PPI) were reported following the realization of significant business actions during the whole period. Major modernizations in this sector were made in 1999 and 2003-2005, but the overall trends suggest that the highest volume of investment of all three sectors of wood processing industry were made into the pulp and paper sector ranging between 1.6 and 6.6 billion SKK per year (Merková *et al*, 2011).

3.4 Effects of investment and FDI in the SR and WPI SR

3.4. Učinci investicija i FDI-a u Slovačku i slovačku preradu drva

Effects of investment and FDI were analyzed through correlation and regression analysis, which was applied to detect dependencies between investment and other economic indicators. Selected analytical results, which demonstrate the positive impact, are presented in Table 15.

The first significant dependence is between foreign direct investment stock in the SR and GDP growth of SR with the correlation coefficient $r = 0.94$, which demonstrates that the growth of FDI causes GDP growth. Regression coefficient $b = 0.000009$ means that the growth of FDI in 100 billion SKK causes the GDP growth of 0.9 % on average.

Subsequent correlation and regression analysis examined the correlation between variables in the wo-

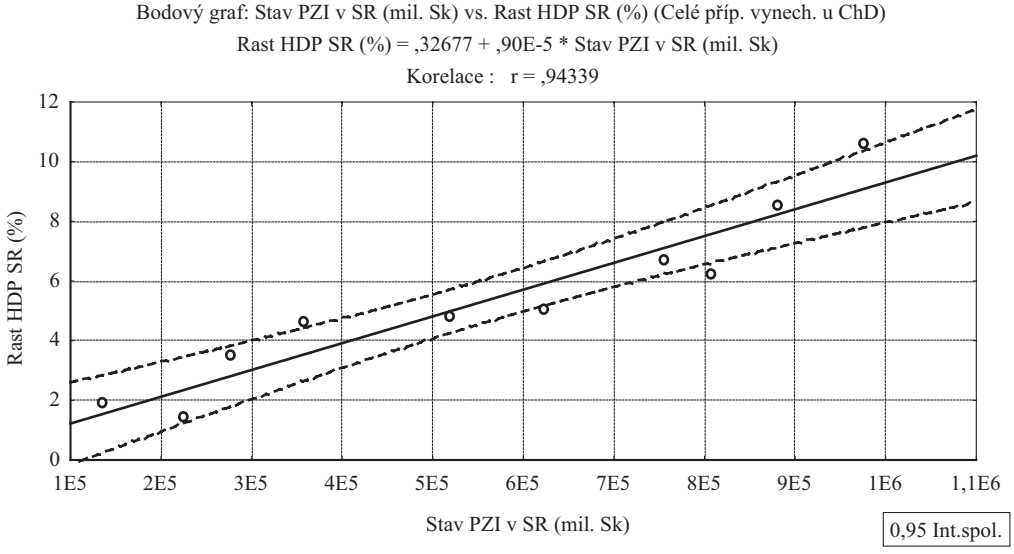

Figure 6 Correlation: FDI stock in SR ~ GDP growth in SR (period 1999-2008)
Slika 6. Korelacija zaliha FDI-a u Slovačkoj i rast BDP-a u Slovačkoj (za razdoblje 1999 - 2008)

Table 14 Selected results of correlation and regression analysis
Tablica 14. Odabrani rezultati korelacijske i regresijske analize

Variables *Varijabla*	**Indicator** / *Pokazatelj*	**Unit** *Mjerna veličina*	**Mean** *Srednja vrijednost*	**Standard Deviation** *standardna devijacija*	**Correlation** r *Korelacija r*	**Determination** r^2 *Determinacija* r^2	**Probability of error** p *Vjerojatnost pogreške p*	**Constant a** *Konstanta a*	**Slope** b) *Nagib b*
X	FDI stock in SR *FDI zaliha u Slovačkoj*	mill. SKK	556 169	297 078					
Y	GDP growth in SR *rast BDP-a u Slovačkoj*	%	5,32	2,83	0,943394	0,889993	0,000042	0,326772	0,000009
X	Investment in WPI *investicije u WPI-u*	mill. SKK	7 527	2 885					
Y	GDP growth in SR *rast BDP-a u Slovačkoj*	%	5,32	2,83	0,842908	0,710494	0,002194	-0,90	0,000826
X	Sales in WPI *prodaja u WPI-u*	mill. SKK	70 017	19 024					
Y	GDP growth in SR *rast BDP-a u Slovačkoj*	%	5,32	2,83	0,944034	0,891201	0,000040	-4,50275	0,00014
X	Value added in WPI *dodana vrijednost u WPI-u*	mill. SKK	15 715	2 587					
Y	GDP growth in SR *rast BDP-a u Slovačkoj*	%	5,32	2,83	0,779587	0,607756	0,007838	-8,06785	0,00085
X	Investment in WPI *investicije u WPI*	mill. SKK	7 527	2 885					
Y	Sales in WPI *prodaja u WPI-u*	mill. SKK	70 017	19 024	0,792267	0,627687	0,006287	30687,77	5,224946
X	Investment in WPI *investicije u WPI*	mill. SKK	7 527	2 885					
Y	Labour productivity of turnover in WPI *produktivnost rada u obrtu WPI-a*	thousands SKK	2 321	607	0,770233	0,593259	0,009143	1100,60	0,162090

od-processing industry of SR, with the focus on the positive impact of investment and the value of fixed assets. Dependence of investment and sales in the WPI showed a correlation coefficient of $r = 0.79$. Regression coefficient $b = 5.22$ means that the growth in investment of 1 billion SKK causes sales growth amounting to 5.22 billion SKK. Dependence of investment and labor productivity in WPI has a similar correlation coefficient $r = 0.77$; the regression coefficient $b = 0.162$ shows that growth in investment of 1 billion SKK causes labor productivity growth of 0.162 million SKK (Figure 10).

Development of the WPI indicators in 2008 and 2009 is due to the financial and economic crisis as well

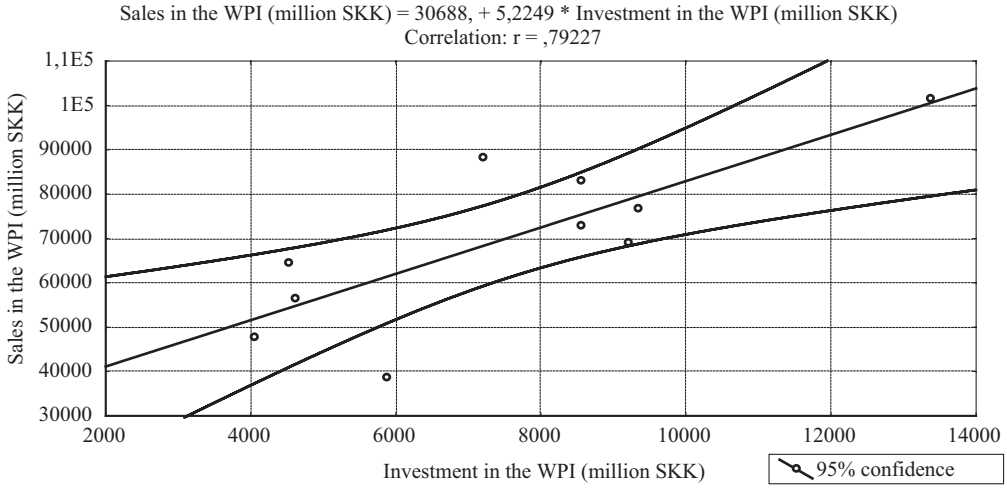

Figure 7 Correlation in the WPI: Investment ~ Sales (period 1999-2008)
Slika 7. Korelacija za investicije i prodaju WPI-a (razdoblje 1999 - 2008)

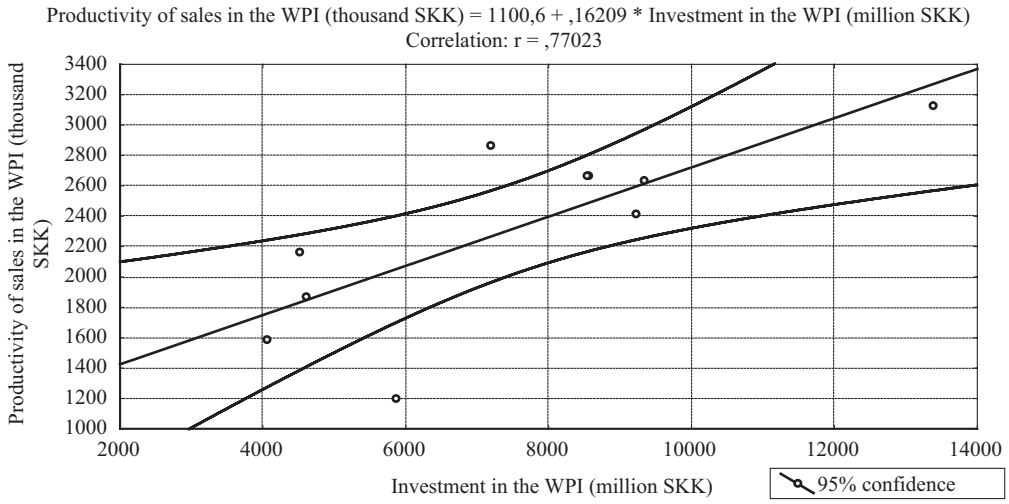

Figure 8 Correlation in the WPI: Investment ~ Labor productivity (period 1999-2008)
Slika 8. Korelacija investicija i produktivnosti rada WPI-a (razdoblje 1999 - 2008)

as to the negative trend caused by unsolved problems for a long time, as shown by the annual decline in sales, value added and profit. Development of selected indicators is shown in Tables 15 to 17.

The employment dropped in all sectors of the WPI and it can be assumed that a smaller number of employees has an impact on labor productivity growth, resulting in wage increases, as correlation and regression analysis showed a high dependence (correlation coefficient 0.95) between labor productivity growth and wage growth.

4 CONCLUSION
4. ZAKLJUČAK

The global financial crisis also had a negative impact on the development of the foreign direct investment flows. Since the end of 2008, global FDI inflows have decreased in all three forms. Equity shares, reinvested earnings and other capital flows (especially inside-corporate loans) fell mainly in developed economies. Investments in equity shares have been reduced due to the weakening of foreign mergers and acquisitions. Lower profits of subsidiary units contributed

Table 15 Selected indicators of wood industry
Tablica 15. Odabrani pokazatelji za preradu drva

Indicator / *Pokazatelj*	2008	2009
Total revenues (mil €) / *ukupni prihod (u mil €)*	569	410
Value added (mil €) / *dodana vrijednost (u mil €)*	104	75
After-tax profit (mil €) / *dobit nakon oporezivanja (u mil €)*	-2	-41
Average number of employees / *prosječni broj zaposlenih*	8 590	6 360
Average monthly wage (€) / *prosječna mjesečna plaća (€)*	581	594

Source: Trend analysis / *Izvor: analiza trendova*

Table 16 Selected indicators of furniture industry
Tablica 16. Odabrani pokazatelji za proizvodnju namještaja

Indicator / *Pokazatelj*	2008	2009
Total revenues (mil €) / *ukupni prihod (u mil €)*	706	573
Value added (mil €) / *dodana vrijednost (u mil €)*	176	161
After-tax profit (mil €) / *dobit nakon oporezivanja (u mil €)*	19	16
Average number of employees / *prosječni broj zaposlenih*	11 960	10 470
Average monthly wage (€) / *prosječna mjesečna plaća (€)*	650	641

Source: Trend analysis / *Izvor: Analiza trendova*

Table 17 Selected indicators of pulp and paper industry
Tablica 17. Odabrani pokazatelji za proizvodnju pulpe i papira

Indicator / *Pokazatelj*	2008	2009
Total revenues (mil €) / *ukupni prihod (u mil €)*	1 403	1 227
Value added (mil €) / *dodana vrijednost (u mil €)*	270	262
After-tax profit (mil €) / *dobit nakon oporezivanja (u mil €)*	83	15
Average number of employees / *prosječni broj zaposlenih*	7 420	6 790
Average monthly wage (€) / *prosječna mjesečna plaća (€)*	904	959

Source: Trend analysis / *Izvor: analiza trendova*

to the decline in reinvested earnings (*World Invesment Report, 2009*). In the period of restructuring of parent companies, foreign subsidiary units were often involved in balancing the outstanding debt.

All economies have been affected by the global crisis in terms of decrease in exports and industrial production, the slowdown of FDI inflows and rising unemployment.

FDI inflows into the region of the V4 countries affect various factors in crisis. In relation to individual V4 countries, however, expectations are primarily the highest average GDP growth over the long term (Slovakia), a large domestic market (Poland) and a relatively stable service sector (Czech Republic, Hungary). The V4 countries in crisis and uncertain investors have the advantage of a predictable and well known environment, in the case of Slovakia even strengthened by the membership in the monetary union.

There is a review of the perception of prices, as investors will certainly not decide for the lowest current price - meaning low production costs and cheap labor or low tax cost - but primarily for the lowest cost throughout the life cycle of the investment (Jelačić *et al*, 2010). Apart from the quality of infrastructure, size of the domestic market or access to regional and international markets, foreign investors will particularly take into account the factors such as energy costs, availability of suppliers and customers, sufficient qualified and skilled workforce, predictability of economic development, stability of legislative conditions, security of companies and others. One of the biggest challenges of the Slovak economy is the ambition to remain an attractive country for foreign direct investment.

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5 REFERENCES
5. LITERATURA

1. Drábek, J.; Jelačić, D., 2007. Investment projects. Zvolen, Vydavateľstvo Nikara, 2007. 65s.
2. Drábek, J.; Merková, M., 2010. Efektívnosť priamych zahraničných investícií v odvetví spracovania dreva. Vydavateľstvo TU Zvolen, pp. 103.
3. Drábek, J., Polach, J. 2008. Reálne a finančné investovanie firiem. Zvolen, Vydavateľstvo TU vo Zvolene, 2008. 271s. ISBN 978-80-228-1934-3.
4. Ferenčíková, S., 2010. Stratégia medzinárodného podnikania: Investície, partneri a ľudské zdroje. Bratislava: Vydavateľstvo EKONÓM, pp. 318.
5. Jelačić, D.; Bičanić, K.; Motik, D., 2010. Croatian wood processing and furniture manufacturing in a time of crisis. In *Ekonomika a manažment podnikov 2010*. CD ROM. Zvolen, p. 70-76.
6. Merková, M., 2010. Vplyv priamych zahraničných investícií na rozvoj odvetvia spracovania dreva. Školiteľ Josef Drábek. Zvolen, Doktorandská dizertačná práca, DF TU Zvolen, pp. 135.
7. Merková, M.; Drábek, J., 2010. Effects and benefits of foreign direct investment for the development of wood-processing industry. In *Wood processing and furniture manufacturing: present conditions, opportunities and new challenges*. Vyhne: 2010. pp.125-133.
8. Merková, M.; Drábek, J., 2011: Potential of effects from foreign direct investment. In *Development trends in economics and management in wood processing and furniture manufacturing*. International Scientific Conference, Kozina, Slovenia, pp.115-124.
9. Merková, M.; Drábek, J.; Polách, J., 2011: Impact of Investment on Labour Productivity Growth in Wood Processing Industry in Slovak Republic. In *Finance and the Performance of Firms in Science, Education and Practice. ISC.* Tomas Bata University in Zlín, Zlín, pp. 324-332.
10. Oblak, L.; Jelačić, D.; Motik, D.; Grladinović, T., 2008. A model for stock management in a wood-industry company. Wood research, 53 (1): 105-116.
11. Okali, I., et al. 2009. Hospodársky vývoj Slovenska v roku 2008. In *Ekonomicky casopis*, 2009, 57 (6): 524-567.
12. Stasiak-Betlejewska, R.; Borkowski, S., 2007. The Role of a Foreign Capital in a Process of the Computerization of the Polish Bank Sector. In *Ekonomika: problemi teorii ta praktiki*. Zbirnik naukovich prac'. Vip. 231. T.IX. Dnipropetrovs'k: Wyd.DNU 2007, pp.1749-1759.
13. Koncepcia riadenia prílevu zahraničných investícií v kontexte globálnej finančnej a hospodárskej krízy. Vypracovalo MH SR v spolupráci s MZV SR. Uznesenie vlády SR č. UV-339/2009.
14. Odporúčania, ako zmierniť následky globálnej krízy v lesnom hospodárstve, drevospracujúcom a celulózovo-papierenskom priemysle. Zvolen: NLC Zvolen, 2009.
15. Správa o stave podnikateľského prostredia v Slovenskej republike s návrhmi na jeho zlepšovanie. Predkladateľ MH SR. Uznesenie vlády SR č. UV-15097/2010.
16. World Investment Prospects Survey 2009-2011. New York, Geneva: UNCTAD, 2008. [online]. Dostupné na internete: http://www.unctad.org/en/docs/diaeia20098_en.pdf
17. World Investment Report 2009. Geneva: UNCTAD, 2009. [online]. Dostupné na internete: http://unctad.org/en/docs/wir2009_en.pdf
18. Act. 565/2007 Coll. The Act of Investment Aid
19. http://epp.eurostat.ec.europa.eu [online].
20. http://www.economy.gov.sk [online].
21. http://www.foreign.gov.sk [online].
22. http://www.nbs.sk [online].
23. http://www.rokovania.sk [online].
24. http://www.sario.sk [online].
25. http://www.statistics.sk [online].

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Prof. dr. sc. Radovan Despot
(14. listopada 1955 – 24. travnja 2012)

Prof. dr. sc. Radovan Despot rođen je u Zagrebu, gdje je živio i školovao se.

A k . g o d i n e 1974/75. upisao se na Šumarski fakultet Sveučilišta u Zagrebu, na Drvno-tehnološki odjel, na kojemu je diplomirao 1980. godine. Tijekom studija kao demonstrator bio je uključen u nastavni rad na Katedri za anatomiju i zaštitu drva, za predmet Anatomija drva, a kao apsolvent honorarno je radio i na znanstvenoistraživačkim temama spomenute katedre. Od 1982. godine do povratka na Fakultet radio je u tadašnjoj RO Industrogradnja, u OOUR-u Proizvodnja i ugradnja građevne stolarije u Lomnici. Na temelju njegova rada kao studenta i demonstratora te rada u struci, njegov mentor prof. dr. sc. Božidar Petrić i mr. sc. V. Šćukanec prepoznali su njegove kvalitete i u travnju 1986. godine doveli ga na Fakultet kao asistenta za predmet Zaštita drva i drvnih proizvoda, gdje je bio zaposlen sve do iznenadne i prerane smrti.

Dana 21. lipnja 1991. Radovan Despot obranio je magistarski rad *Poboljšanje permeabilnosti jelovine djelovanjem bakterija*, a u zvanje znanstvenog asistenta izabran je u siječnju 1992. godine. Od 7. veljače 1989. godine upisan je u registar istraživača Ministarstva znanosti i tehnologije Republike Hrvatske. Doktorsku disertaciju pod naslovom *Prilog poznavanju mehanizma infekcije i truljenja jelove građevne stolarije* Radovan Despot obranio je 4. studenog 1996. godine. Početkom 1997. godine izabran je za višeg asistenta za predmet Zaštita drva i drvnih proizvoda, a 26. lipnja iste godine izabran je u znanstveno-nastavno zvanje docenta za isti predmet. Godine 1999. prvi je put izabran za pročelnika Zavoda za istraživanja u drvnoj industriji (ZIDI), a 2001. ponovno je izabran, i tu je dužnost obnašao sve do 2002. godine, kada preuzima dužnost prodekana Drvnotehnološkog odsjeka Šumarskog fakulteta Sveučilišta u Zagrebu, kao i dužnost predstojnika Zavoda za ploče i kemijsku preradu drva. Tijekom svibnja 2002. godine zbog svog je dotadašnjeg rada i zalaganja izabran za dopisnog člana Akademije šumarskih znanosti. U znanstveno-nastavno zvanje izvanrednog profesora izabran je 21. veljače 2007, a u znanstveno-nastavno zvanje redovitog profesora izabran je početkom 2011. godine. U akad. god. 2007/2008. i 2008/2009. prof. dr. sc. Radovan Despot obnaša dužnost prodekana za znanstvenoistraživački rad Šumarskog fakulteta Sveučilišta u Zagrebu.

Od samog početka bavljenja znanstvenim radom prof. dr. sc. Radovan Despot sudjelovao je u pet nacionalnih znanstvenoistraživačkih projekata, od kojih je na dvama bio i voditelj. Također je sudjelovao i bio glavni voditelj triju međunarodnih bilateralnih znanstvenoistraživačkih projekata. Objavio je više od 100 znanstvenih i stručnih radova zemlji i inozemstvu. Prof. dr. sc. Radovan Despot u dva je navrata boravio u Building Research Establishment Institutu u Garstonu, u Velikoj Britaniji. Godine 1998. postaje članom IRG-a (International Research Group on Wood Protection) te je od 1998. do smrti aktivno sudjelovao na više IRG-ovih međunarodnih znastvenih konferencija na kojima je više puta bio moderator pojedinih sekcija. Prof. dr. sc. Radovan Despot kao autor i suautor znanstvenih radova više je puta sudjelovao na međunarodnim kongresima Wood structure and properties (Zvolen, Slovačka) i na European Conference on Wood Modification, a od samog je početka bio član znanstvenih i programskih odbora međunarodnih konferencija *Drvo u graditeljstvu*, *Ambienta* i SHATIS (Structural Health Asesment of Timber Structures). Bio je član uredničkih odbora i izdavačkih savjeta više međunarodno priznatih znanstvenih časopisa s područja drvne tehnologije. Godine 1999. postao je članom europske organizacije COST (European Cooperation in Science and Technology). Najprije je bio član COST akcije E22, a potom postaje članom COST akcija E31 i E37. Od 2000. do 2004. godine uspostavio je putem COST-a značajniju suradnju s BFH Institutom u Hamburgu (Bundesforschungsanstalt für Forst- und Holzwirtschaft). Za znanstvenog novaka Marina Hasana u sklopu te suradnje osigurao je dva znanstvena boravka (tzv. Short Term Scientiffic Mission) u spomenutom institutu. Godine 2004. Ministarstvo znanosti, obrazovanja i sporta imenovalo ga je *nacionalnim koordinatorom COST-a* za područje šumarstva i drvne tehnologije (Domain Committe for Forest, Forestry Products and Services), a 2010. godine ponovo je izabran na istu dužnost, koju je do zadnjeg dana vrlo aktivno i predano obnašao. Svojom zapanjujućom energijom i entuzijazmom potaknuo je i u međunarodnu suradnju uključio mnoge mlade znanstvenike i kolege.

Svoj interes za nastavu prof. dr. sc. Radovan Despot pokazivao je stalnim sustavnim metodičkim i tehničkim osuvremenjavanjem nastave. Za studente Šumarskog fakulteta bio je jedan od najboljih i najomiljenijih nastavnika. Sudjelovao je u ocjeni nekoliko desetaka diplomskih radova, a bio je mentor dvadesetak diplomskih, dvaju magistarskih radova i jedne doktorske disertacije. Do zadnjeg je dana s mnogo obzira, pažnje, žara i entuzijazma pripremao vođenje još

dvaju doktoranada u izradi njihovih doktorskih disertacija. Tri je puta bio član povjerenstva za obranu doktorske disertacije (od toga dvaput u inozemstvu), više puta član povjerenstva za obranu magistarskog rada, a više je puta bio član povjerenstva za izbor nastavnika u više znanstveno-nastavno zvanje u Hrvatskoj i inozemstvu. U sklopu izrade novih studijskih programa preddiplomskih studija drvne tehnologije u Zagrebu i Virovitici te diplomske i poslijediplomske nastave u Zagrebu kreirao je i uveo više od deset novih predmeta. Na poslijediplomskom studiju iz znanstvenog usmjerenja Vođenje procesa u preradbi drva bio je voditelj izborne skupine Zaštita drva, a od 2005. godine bio je i voditelj novog modula Modifikacije drva na poslijediplomskom doktorskom studiju Drvne tehnologije. Kao gost predavač, Radovan Despot je 1999. godine boravio u Ljubljani, gdje je za studente diplomskog studija Oddelka za lesarstvo Biotehniške fakultete održao više predavanja.

Prof. dr. sc. Radovan Despot bio je član Akademije šumarskih znanosti, Hrvatskoga šumarskog društva, Društva nastavnika i Hrvatske komore inženjera šumarstva i drvne tehnologije, u kojoj je bio imenovan članom povjerenstva za napredovanje i edukaciju kadrova.

U znanstvenoistraživačkom radu prof. dr. sc. Radovan Despot bavio se istraživanjem mehanizma i sukcesije abiološke i biološke razgradnje drva u upotrebi, identifikacijom štetnika u drvu, postupcima zaštite i modifikacije drva, sterilizacijom, zaštitom i konzervacijom drvenih umjetnina i objekata kulturne baštine na području Hrvatske. Izradio je više desetaka stručnih mišljenja i ekspertiza te je više puta bio član nadzornog tijela pri restauratorskim zahvatima na objektima kulturne baštine (npr. paviljonu Jeke, Vidikovcu i Švicarskoj kući u Maksimiru, Tehničkome muzeju u Zagrebu i mnogim drugim objektima diljem Hrvatske). Intenzivno se bavio i ekološkim načelima zaštite drva te bio aktivni član europskog COST projekta za zbrinjavanje drvnog otpada i kemijski zaštićenog drva, kogeneraciju i dobivanje ekološki čišće energije.

Približavanjem Republike Hrvatske ulasku u Europsku Uniju prof. dr. sc. Radovan Despot intenzivno je radio na prilagođivanju propisa domaće drvnotehnološke struke europskim i svjetskim normama, pri čemu je bio i kreator Pravilnika i utemeljitelj fitosanitarnog sustava Republike Hrvatske sukladnoga međunarodnom standardu ISPM 15. U izgradnji i razvoju navedenog sustava, a time i hrvatskoga gospodarstva, godinama je održavao i unaprjeđivao fitosanitarni sustav stotinjak tvrtki. Na temelju njegova rada i zalaganja, velik se dio tih tvrtki iz Hrvatske probio na europsko tržište i time si osigurao dugoročni prosperitet.

Prof. dr. sc. Radovan Despot bio je nesalomljivi entuzijast, znanstvenik predan implementaciji znanosti u razvoj gospodarstva. Bio je čovjek koji je uz brojne obveze vezane za svoj profesorski habitus uvijek pronašao vremena za svoju užu obitelj i rodbinu te tople riječi za svoju veliku obitelj, a to su njegovi brojni prijatelji diljem svijeta. Dragi naš profesor Despot otišao je, no nije nas napustio. Svijetli lik, uvijek pozitivan odnos, velika potpora i razumijevanje te plemenita djela ponajprije čovjeka i prijatelja, kolege i profesora ostat će trajno u našim mislima i našim srcima, a brojne generacije njegovih studenata još će se dugo sjećati jednoga od najvećih i najomiljenijih profesora Šumarskog fakulteta.

Neka mu je vječna slava i hvala za dobrotu, toplinu, prijateljstvo i znanje koje je nesebično pronosio.

dr. sc. Marin Hasan

Upoznavanje s novim računalnim Autodeskovim programima

U sklopu terenske nastave za studente Drvnotehnološkog odsjeka Šumarskog fakulteta, diplomskog studija, smjera Oblikovanje proizvoda od drva, organizirana je radionica u tvrtki Prior inženjering d.o.o. Tvrtka Prior zastupnik je i edukator za Autodeskove programe, a za Šumarski je fakultet donator informatičke opreme i posrednik u Autodeskovoj donaciji 30 licencija programa AutoCAD, Inventor i AutoCAD Mechanical, koji služe u redovitoj nastavi različitih kolegija na Šumarskom fakultetu. Radionica je obuhvaćala prezentaciju i rad na računalima u učionici tvrtke Prior, i to na Autodeskovim programima trodimenzionalnog modeliranja i vizualizacije paketa Product Design suite. Nakon kratkog uvoda o Autdesku i promotivnog filma počelo je upoznavanje s novom i poboljšanom verzijom programa AutoCAD. Studenti su, uz vodstvo predavača tvrtke Prior Zdenka Kožara, imali priliku isprobati najnovije verzije programa.

Slika 1. Studenti druge godine diplomskog studija, smjera Oblikovanje proizvoda od drva, s voditeljem radionice Zdenkom Kožarom u učionici tvrtke Prior inženjering d.o.o.

Slika 2. Studentica Marina Jajčinović izrađuje crtež u programu SketchBook Designer

Slika 3. Voditelj radionice Zdenko Kožar s prikazom vizualizacije u programu Showcase

Nakon crtanja u programu AutoCAD uslijedila je demonstracija ostalih Autodeskovih programa kao što su Autodesk 123D Catch, koji od niza fotografija željeni objekt pretvara u trodimenzionalni oblik. SketchBook Designer program je za skiciranje namijenjen umjetničkom crtanju i potrebama konceptualnog oblikovanja. Program Showcase namijenjen je arhitektima, dizajnerima, inženjerima i marketinškim stručnjacima. Pretvaranjem AutoCAD-ovih projekata u trodimenzionalne prezentacije taj program služi za vizualizaciju dizajnerskih rješenja i njihovih inačica. Danas nezaobilazni program za dizajniranje, modeliranje i vizualizaciju u automobilskoj idustriji i oblikovanju proizvoda široke potrošnje Alias, također je predstavljen na radionici. Većina programa usklađena je s potrebama drvne struke te proizvodnje i prodaje namještaja.

Kada se u području proizvodnje namještaja i drvnih proizvoda spominje program AutoCAD, najčešće se misli na izradu dvodimenzionalnih tehničkih crteža, no razvojem dijela programa koji obrađuje vizualizaciju s primjenom svjetla i bibliotekom velikog broja tekstura, AutoCAD omogućuje izradu fotorealističnih vizualizacija, s mogućnošću prikazivanja u realnom vremenu - animacije. To se područje dosad najčešće obrađivalo programom Autodesk 3ds Max.

Studenti su imali priliku steći uvid u dodatne mogućnosti međusobne interakcije spomenutih programa. Iako u prvi mah mogućnosti programa mogu prestrašiti, treba imati na umu da su programi za crtanje, trodimenzionalno modeliranje i vizualizaciju kompleksni i zahtijevaju neprekidno učenje. Nerealno bi bilo očekivati da je u vremenu od nekoliko sati, koliko su studenti bili na edukaciji, moguće naučiti koristiti se svim navedenim programima. Ovim posjetom studentima je dan u pregled ponude i mogućnosti programa

a) b) c) d)

Slika 4. a) i b) AutoCAD vizualizacija pri dnevnoj svjetlosti s pogledom na hodnik i prema prozoru; c) s neonskom rasvjetom radne plohe; d) sa stropnom rasvjetom; Zdenko Kožar, PRIOR inženjering d.o.o

a) b)

Slika 5. AutoCAD vizualizacija prostora s inačicom različitih upotrijebljenih materijala; Zdenko Kožar, PRIOR inženjering d.o.o

koji su nezaobilazni alat u konstruiranju i oblikovanju namještaja i unutarnje opreme. Takav oblik prezentacije noviteta prilika je za brže upoznavanje s programima i njihovim novostima, što je struci od neprocjenjive važnosti. Upotreba navedenih programa skraćuje vrijeme izrade tehničke dokumentacije, smanjuje mogućnost pogreške te kvalitativno jamči veću preciznost, a time i uštedu u proizvodnom procesu.

doc. dr. sc. Silvana Prekrat
Marina Jajčinović

Posjet studenata Drvnotehnološkog odsjeka Elgradu i Eggerovoj izložbi

Na izložbi Interzum u Kölnu 2012. na štandu tvrtke Egger bio je izložen kamion posebno naručen za prezentaciju proizvoda tvrtke Egger. Nastavnici Drvnotehnološkog odsjeka, uz izvrsno vođenje zastupnika tvrtke Egger Igora Tomića, utvrdili su korisnost te prezentacije. Proputovanje Eggerova kamiona uključivalo je Zagreb kao jedno od mjesta prezentacija. S voditeljem prodaje Deanom Balentom dogovoren je posjet studenata Drvnotehnološkog odsjeka Šumarskog fakulteta. Tvrtka Elgrad bila je i domaćin tvrtki Egger, jednoj od vodećih tvrtki u proizvodnji i oplemenjivanju pločastih materijala.

Nakon kratkog uvoda u poslovanje tvrtke studenti su, uz stručno vođenje voditeljice poslovnice na Žitnjaku Suzane Kovačević, razgledali ponudu drvnih pločastih materijala i okova koje nudi Elgrad.

Novitet u Elgradu je 3D prezentacijski prostor u kojem se na trodimenzionalnim projekcijskim površinama mogu projicirati slike korpusnog namještaja radi vizualizacije različitih dekora koji se nude, što olakšava odabir boje i teksture oplemenjenih drvnih ploča. Jednostavnim dodirom zaslona može se promijeniti oblik i boja poda, zida te teksture i njezina smjera. Takav način prezentacije posebno je namijenjen kupcima koji nisu neposredno vezani za djelatnost opremanja objekata i oblikovanja namještaja.

U velikoj ponudi različitih dekora, tekstura folija i laminata ističu se imitacije kamena, drva i metala za namještaj i laminatne podove, kao i MDF ploča visokog sjaja koje su u posljednje vrijeme u trendu te za koje je nemoguće na pogled i dodir utvrditi je li riječ o pravome materijalu ili o imitaciji. Jedan od zapaženih noviteta jest lasersko oblaganje rubova. Tim se postupkom prijelaz između plohe i ruba gotovo i ne vidi, a posebno je primjenjiv za ploče visokog sjaja. Namještaj od ploča oplemenjene folijom tim postupkom oblaganja rubova ulazi u viši cjenovni razred.

Studenti su mogli vidjeti sve vrste neoplemenjenih ploča iverica i vlaknatica, rubne trake, akustične ploče, ploče oplemenjene folijama i laminatima, lagane, debljinski uslojene ploče, OSB ploče, laminatne podove, soft i postforming elemente (prozorske klupčice, radne kuhinjske ploče, pročelja za namještaj) te kompozitne ploče. Osobito zanimanje studenti su pokazali za uslojene, debljinski spajane ploče iverice debljina 3, 4 ili 8 mm, s ispunama od papirnog saća, pod nazivom Eurolight decor ploče. Tim je pločama moguće proizvesti namještaj većih debljina, čak i do 100 mm, čime se postiže masivan izgled namještaja koji unatoč izgledu ima malu masu.

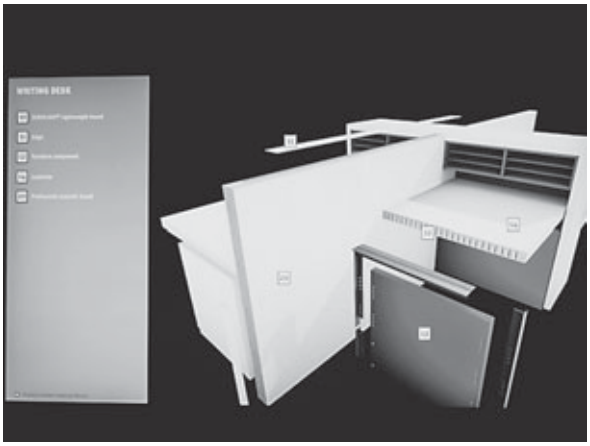
Prezentacija tvrtke Egger u prezentacijskom kamionu stručno je vodio Dean Balent, pri čemu su studenti u nekoliko grupa imali priliku upoznati materijale i tehnologiju izrade drvnih ploča koje proizvodi Egger.

Izložba u kamionu započela je predstavljanjem ponude digitalnog tiska na drvnim pločama što ga tvrtka Egger izrađuje na osnovi fotografije ili uzorka kreiranih po narudžbi kupca, a koji je zbog isplativosti limitiran samo minimalnom količinom narudžbe.

Slika 1. Voditeljica poslovnice Elgrad Suzana Kovačević pokazuje proizvodni program te tvrtke

Slika 2. Primjer tiskanog uzorka na drvnim pločama namijenjenim oblaganju zidova i podova te sirovina za proizvodnju Eggerovih drvnih ploča

Slika 3. Uz pomoć hologrami Dean Balen objašnjava proces proizvodnje ploča od sječe stabala do recikliranja ploča dotrajalog namještaja



Slika 4. U prostoru rastavljeni (eksplodirani) trodimenzionalni model s prikazom upotrijebljenih materijala u konstrukciji uredskog namještaja

Slika 5. Prezentacija koncepta boja i dekora namijenjena željenom prostoru

Posjet studenata Drvnotehnološkog odsjeka Elgradu i Eggeru završio je prezentacijom kuhinjskog namještaja, pri čemu je u program EGGER Virtual Design Studio unesena fotografija interijera kojemu treba odrediti dekore namještaja. Taj program služi za bolju percepciju različitih dekora te boja i tekstura zidova i podova kako bi se ti elementi što bolje međusobno uskladili i kako bi se odabrao prikladan materijal. Na odlasku su studentima i nastavnicima predani promotivni materijali i uzorci drvnih ploča koje se upotrebljavaju u nastavi.

Slika 6. Dean Balent prikazuje studentima novitete u proizvodnji dekora

Slika 7. Vizualizacija kuhinje uz pomoć programa EGGER Virtual Design Studio

doc. dr. sc. Silvana Prekrat
Marina Jajčinović

IMM COLOGNE 2012 METROPOLA ZA POSLOVNE ELITE

Premda je sajam IMM Cologne daleko iza nas i dijeli nas već gotovo pola godine otkako je ta manifestacija završena (kao podsjetnik, IMM - International Möbel Messe, tradicionalno se održava svake godine sredinom siječnja u Kölnu), svakako treba zabilježiti utjecaj toga najvećeg međunarodnog sajma namještaja i prateće industrije, koji uistinu postavlja i diktira najnovije trendove.

U paviljonima IMM-a sve je samo ne hladno (sl. 1). Naprotiv, živa vreva promatrača i izlagača, noviteti na svakom koraku, boje, materijali… pomalo vam se, ako niste navikli na svu tu gužvu i vrevu, počne vrtjeti u glavi od novosti i vizualno-slušnih „napada“. Uz sve što gledate, ne treba zaboraviti da je IMM mjesto susreta s poslovnim partnerima, središte razgovora i, vrlo često, poslovnih dogovora iz kojih kasnije bivaju lansirani brojni proizvodi na globalno svjetsko tržište. Tu se ostvaruju kontakti poslovnih subjekata iz svih područja trgovine i industrije, susreću se poslovni stručnjaci, stručnjaci za arhitekturu i interijer te stručnjaci iz mnogih drugih sektora, posebice mladi profesionalci i dizajneri koji se žele etablirati i naći svoje „mjesto pod suncem“. Poslovni posjetitelji na sajam dolaze s namjerom da posluju, a nerijetko to i ostvare.

Living Interiors već je neko vrijeme novi oblik „sajmovanja“, pri čemu se posjetitelju prikazuje savršeno postavljen svijet unutrašnjeg uređenja stambenoga i javnog prostora koji se sastoji od namještaja, kupaonica, podova, zidova i rasvjete. Na taj se način žele privući novi kupci koji svake godine proizvođačima i trgovcima postavljaju nove prezentacijske zahtjeve. U Kölnu takav pristup doseže vrhunac inventivnosti.

Ukratko, Köln je i ove godine, unatoč krizi o kojoj se već toliko priča da o tome i „vrapci znaju“, zabljesnuo u novome, entuzijazmom obojenom ozračju.

Slika 1. Službena naslovnica ovogodišnjeg sajma

Kao dokaz govore i brojke: sajam je posjetilo više od 138 000 posjetitelja iz 128 zemalja svijeta. Poslovno ili privatno, oni su mogli razgledati izložene proizvode 1 213 izlagača iz 48 zemalja svijeta.

Za početak, prošetajmo sajmom uz kraće natuknice i neke zanimljivosti…

Das Haus - interijeri na pozornici

Pod naslovom *Das Haus - interijer na pozornici*, Imm Cologne nastavlja tradiciju idealnih kuća, „iako bez usvajanja apstraktne dimenzije prostora za život”, objašnjava Dick Spierenburg, pod čijim je vodstvom kreativni tim Koelnmessea razvio i proveo taj projekt. Umjesto toga, Imm Cologne je želio povezati stvarne uvjete gradeći most između industrije opremanja proizvoda i progresivno kreativnih tvrtki koje pokreću internacionalna dizajnerska imena.

Projekt se ove godine fokusirao na izradu umjetnih životnih situacija na samom sajmu i na stvaranju osobnoga životnog prostor što su ga dizajnirali Nipa Doshi i Jonathan Levien.

U sredini paviljona *Pure Village* bio je podignut prezentacijski prostor od 180 m^2 kako bi se promovirali svi sadržaji i postavi novih načina prikazivanja interijera.

Das Haus - Interijer na pozornici prikazuje strukturu koja je potpunosti u skladu s korisnikom (sl. 2. i 3). Dizajner postavlja i prezentira ideju, arhitektonski element, unutrašnjost i vanjski prostor, postave namještaja i elemenata za opremanje tako da individualno

Slika 2. *Das Haus* – interijeri na pozornici

Slika 3. *Das Haus* – interijeri na pozornici

oblikuje prostor prema svačijoj mjeri. *Das Haus - interijer na pozornici* predstavljen je s jedinstvenom namjerom da se prikaže mogućnost vlastite ekspresije u oblikovanju privatnih svjetova.

Nova sinergija

Zapitamo li se katkada kako izgleda pozadina svakoga velikog događanja, kada se posjetitelji prepuste euforiji koja ih ponese i kada zajedno zavibriraju tisuće ljudi koji su došli s ushićenjem pogledati što ima novo? Kada u stvarnosti doživimo tu rijeku, tek onda možemo reći da smo bili, vidjeli i uistinu ostali zatečeni.

Razgovarajući s organizatorima sajma, dolazimo do zaključka da je recesija stanje svijesti u kojemu se može zateći društvo bez jasnog cilja. Sajam kao da se nalazi na drugom planetu koji ne želi prihvatiti možebitnu stvarnost. On izlaže i promiče nove koncepte, nove prostupke uređenja prostora i mijenja stajališta svih korisnika (sl. 4).

Slika 4. Novi koncepti uredskoga i školskog sjedenja

Frank Haubold, glavna i odgovorna osoba sajma, donio je odluku da sajam postane dio motora koji će pomoći da lokomotiva koja mora povući kompoziciju iz recesije bude uspješna. I uspio je.

„Rast je ključna riječ koja opisuje naš poslovni plan“ – riječi su Franka Haubolda. Možda ne toliko fizički rast sajma, ali sigurno rast ponude i mogućnosti kojima treba privući pozornost klijenta, kako poslovnih, tako i privatnih klijenata koji na sajam navraćaju samo da bi opremili privatni prostor. „Tvrtke kao da su zanemarile malog kupca na sajmovima, a sajam se u biti i organizira da bi proizvođači i trgovci prodali svoj proizvod krajnjem korisniku.“

Usmena predaja i preporuka najbolja su reklama. Kupac će prihvatiti ili odbaciti pojedini proizvod, a prikupljanje podataka o tim procesima možda je najbitniji segment jer kupac na taj način određuje što će postati trend, a što nikada neće izaći na globalno tržište.

[D ³] Dizajn talenti

[D³] - Design talents

Sedmi put kreativni i inovativni mladi dizajneri na Imm Cologne predstavili su svoje ideje i koncepte u natječaju *[D³] - Dizajn talent.*

[D³] Contest

Deveti put međunarodno priznato natjecanje u dizajnu [D ³] nudio je studentima i tek diplomiranim autorima iz cijelog svijeta mogućnost da svojim projektima nadahnu međunarodnu scenu dizajna. Oni koji od Imm Cologne dobiju poziv za sudjelovanje već su pobjednici jer biva odabrano samo 28 proizvoda od više od 650 prijava, 32 dizajnera iz 11 nacija.

[D³] Professionals

Na području *[D³] Professionals* mladi, neovisni dizajneri i dizajnerski studiji predstavljaju prototipove i proizvode koji se prodaju zasebno. Taj paviljon uistinu je oličenje kreativnosti, instoracije, pozitivnog duha i nade u slobodu djelovanja i stvaranja (sl. 5).

Slika 5. *Cloud stool*

Istaknuti trendovi na IMM-u 2012

Drvo je i dalje u trendu, osobito prirodni izgled drva. Najčešće se upotrebljava izbijeljeni, svijetli hrast, čija je površina gruba, “hrapava” i naglašeno prirodna. Ako se rabe druge vrste drva, trendovi daju prednost svjetlijim bojama i vidljivim godovima. Osim drva kao prirodnog materijala namještaja, omiljena dekoracija postaju jelenji rogovi u prirodnome ili stiliziranom izdanju. No u nedostatku tih rogova, poslužit će rogovi drugih životinja. Lovci tim hitom konačno dolaze “na svoje”.

Važnu ulogu imaju i dekorativne tkanine, a preferiraju se karirani i prugasti uzorci. Cvjetni se pojavljuju samo u detaljima. Popularni su i printovi u krupnom mjerilu. Takve su tkanine osobito preporučljive za ojastučeni namještaj dječjih i mladenačkih soba. Sjedeće garniture moraju zadovoljiti uvjete zdravoga i odmarajućeg sjedenja i ležanja, pa su redovito većih dimenzija ili s multifunkcionalnim dodacima koji ih pretvaraju u ugodan ležaj. Modularnost im omogućuje različite načine slaganja u prostoru. Uz njih se postavljaju neizostavni čupavi ili kožni tepisi.

Omiljene su boje i dalje bijela, u mat i sjajnoj verziji, siva u svim nijansama, zagasito smeđa – od nijansi bijele kave do tamnijih, plava, pogotovo u petrolej nijansi, te ljubičasta, a smjelo se pojavljuju nijanse ružičaste, narančaste i zelene, koje svojom zastupljenošću daju jake naglaske.

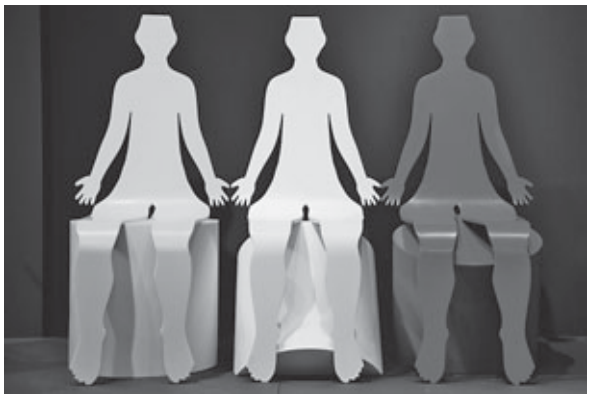
Posljednjih nekoliko godina postaju popularne i zidne obloge. Različite vrste kamena i tapeta i dalje su u modi, ali obloge s 3D efektom, kao odraz Interzuma, koje zidovima daju novu dimenziju, postaju nezaobilazan detalj. Te se obloge mogu postavljati u svim prostorima, od ulaza do spavaće sobe ili kupaonice, a efekti se pojačavaju rasvjetom. I dalje su u trendu velika rasvjetna tijela, kao i LED rasvjeta unutar namještaja.

U svakom slučaju, ovogodišnji su trendovi ostavili priličnu slobodu u odabiru stila, boja i materijala te time ostali dosljedni ideji koju promiču, a to je mogućnost kreiranja prostora prema individualnim potrebama. To je svakako najveća vrijednost novih trendova!

Koncept i integracija - dva su pojma koja objašnjavaju trendove i smjernice današnjice. Danas ljudi gledaju TV u kuhinji, kade se integriraju u spavaće sobe, stari se namještaj kombinira s novim, a ako to netko poželi, hodnik vlastitoga doma može pretvoriti u prostor za zabavu i tulume. Taj osjećaj slobode unutar vlastita četiri zida pruža brojne mogućnosti za izražavanje nečijega individualnog identiteta i neovisnog smisla za dizajn (sl. 6 i 7).

Udobnost prostora kao u dvoranama 4.1, 5.2, 6 i 10.2, toliko ojastučenog namještaja koji u svojoj punini dočarava svaki aspekt udobnosti – nećete naći nigdje drugdje. Svake godine tijekom IMM-a to se područje pretvara u globalnu meku za ojastučeni namještaj. Wi-

Slika 6. Neki oblici samo mijenjaju boju, ali ćud ostaje



Slika 7. Antropomorfni furnirski otpresci

Slika 8. Novitet iz tvrtke Schillig

Slika 9. Nova generacija ležajeva-madraca

lli Schillig predstavio je novi dizajnerski vokabular na primjeru "16650" sjedala, model iz *boogie* serije (sl. 8). Osim u obliku, ključni su aspekti tog sjedala različite funkcije, koje postaju vidljive tek na drugi pogled i čini se da su nužne svakom kupcu nakon što on isproba te nove koncepte. *Ergolux - ergonomski i luksuzan* naslon za ruke dokazuje svoju vrhunsku kvalitetu na IMM Cologneu 2011, a sada se uspješno primjenjuje u modelu "16650".

Snovi posjetitelja zasigurno su se ostvarili kada su vidjeli proizvode u dvorani 9 (sl. 9). Od ležaja-madraca i sustava za spavanje, posteljine i drugih srodnih proizvoda, taj pregled proizvoda obuhaća proizvođače iz cijelog svijeta. Dva potpuno nova koncepta vodenog kreveta mogla su se vidjeti na štandu *Aqua* vodeni kreveti, u dvorani 9.1. Danski dizajner Per Weiss razvio je dizajnerski koncept visokokvalitetnih *boxspring* ležajeva-madraca, kao i široku paletu dodatnih proizvoda, uključujući noćne ormariće, police i različite vrste zaglavlja kreveta.

Dynaglobe je cijele sezone pripremao iznenađenja i potvrdio da su voda i zrak ne samo dva elementa nužna za čovjekov život već i za dizajn sustava za ležanje i spavanje.

Noviteti tvrtke *Kluso*, pod imenom *Cubana – Beds in motion*, prikazani su na slici 10. Mogućnost regulacije sustava za spavanje uz pomoć iPhone aplikacije? Zaista, multimedija osvaja sve pore života.

Mnogi se drugi koncepti provlače kroz cijeli prezentacijski dio , a dizajneri, proizvođači i trgovci iskorištavaju svaku priliku da u svoj asortiman uključe neku novotariju koja će privući kupca. Konkurencija je neumoljiva i uspijevaju samo najveći, najjači i najsnalažljiviji.

U posljednje se vrijeme bilježi i porast razvojnih dizajnerskih studija koji svoje usluge nude velikim proizvođačima. Nipa Doshi i Jonathan Levien dvojac

Slika 10. Krevetni sustav tvrtke Kluso

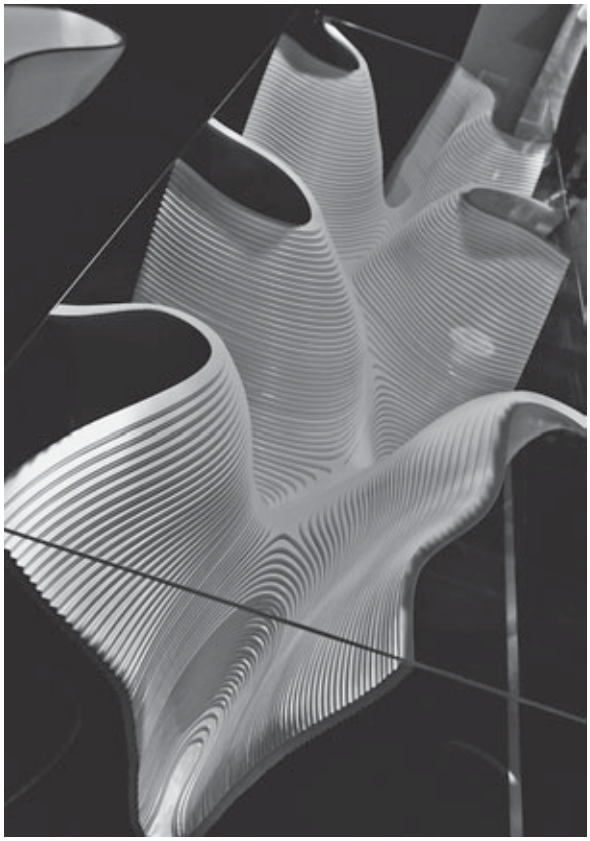
Slika 11. Nipa Doshi i Jonathan Levien

je koji se uspinje upravo prije spomenutim pravcem. Puristički dizajn i egzotični šarm ono su što opisuje njihov rad. Odabrani slučajno iz cijele vojske kreativaca okupljene na sajmu, možemo reći i da su svojevrsni predstavnici novih tendencija u razvoju dizajna interijera (sl. 11).

Promišljenost, ekonomičnost, ekologičnost, ergonomija, znanost isprepletena s umjetnošću – tržište je odlučilo da ponovno želi pomno promišljen proizvod s pozadinskom pričom, kupac traži legendu koju može prepričavati dok s društvom sjedi na svojoj novoj garnituri u dnevnom boravku, koji je zapravo dio kuhinje, ali se noću pretvara u disko klub koji nakon odlaska gostiju polako sniva spavaću sobu.

Noviteti su na svakom koraku, od novih materijala, konstrukcija, oblika, sve do načina oblikovanja namještaja i opremanja prostora (sl. 12 - 15).

Ukratko, mogli bi se izdvojiti sljedeći trendovi za 2012. godinu.



Slika 12. 3D ploče, reljefno postolje stolića

Slika 13. Stolice od furnirskih otpresaka

Što ostaje u trendu

- Bijela kao glavna boja za ojastučenje i vidljive površine namještaja
- Dnevni boravak s LCD monitorima te dugačkim, visokim i niskim ormarićima
- Kuhinja – blagovaonica – dnevni boravak spojeni u jedinstveni životni prostor

Slika 14. Namještaj od MDFi furnirskih ploča

Slika 15. Direktna aplikacija vizuala na MDF ploče digitalnim tiskom

– Namještaj detaljno obrađen sa svih strana, s mogućnošću samostalnog postavljanja u prostoru
– Dominiraju čiste, jednostavne boje kao obložne tkanine
– Šarene pruge ili apstraktne grafike popularan su izbor za naglašavanje
– Podesivi ojastučeni namještaj prema individualnim potrebama
– Udobni blagovaonički stolci i pravokutni stolovi
– Bijela tehnika koja štedi energiju

Što postaje trend

– Unikatan i izuzetno obrađen *green design* namještaj
– Prirodni tonovi i jarke boje, osobito ružičasta, zelena i plava
– Pokrivne tkanine na ojastučenom namještaju prema uzoru na „bakin stil“ prepun cvjetića i ručnog veza
– Koloristički akcenti pojačani LED rasvjetom u kuhinji, ormarima i garderobi; ta štedna rasvjeta ispunjava većinu garderobnih ormara, regala, bočne stranice i vitrine i ima dvije funkcije: daje svjetlost i stvara određeni ugođaj
– Privatne spa oaze između kupaonice i spavaće sobe
– Tamno i svijetlo drvo (orah, hrast) u kombinaciji sa staklom i čelikom
– Nanopremazi na površinama
– U segmentu kože – gusta, jedva obrađena prirodna koža s opipljivim, primamljivim karakterom posebno je popularna
– Dnevna soba kao privatni prostor – dominiraju mir i masažne fotelje
– Održivost i filozofija održivog razvoja preuzela je glavnu ulogu u izradi namještaja. Drvo postaje popularnije, ne samo za kuhinjski namještaj i namještaj za pohranu, već i za udobne stolce i ležaljke te kao vidljivi dio gotovo svakog komada namještaja. Drvo vraća svoj prijašnji status u proizvodnji i osmišljavanju svih dijelova interijera.
– Svijetlo drvo kao da u kontrastu s tamnim ili potamnjenim vrstama stvara živi prirodni kontrast
– Organske forme uobličene od furnirskih otpresaka dovode drvo u sasvim nove funkcionalne i dekorativne dimenzije

Glavni trend koji će se provlačiti kroz ovu sezonu jest potreba da se izraziti smjer razvoja i prepoznatljivosti trendova „smekšava”.

Prilagođivanje individualnom kupcu čimbenik je koji definira pojedini proizvod. Sloboda i liberalizacija oblika, boja i funkcija možda je najbolji način da opišemo dolazeće trendove.

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dr. sc. Danijela Domljan, magistrica dizajna
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Izdvojeni kutak hrvatskih izlagača na IMM Cologne 2012

U organizaciji HGK, Sektora za poljoprivredu, prehrambenu industriju i šumarstvo i Sektora za trgovinu, u suradnji s Ministarstvom poljoprivrede, Upravom za drvnu industriju i Ministarstvom gospodarstva na Međunarodnom sajmu namještaja IMM COLOGNE 2012, u Kölnu se, na sajmu IMM, predstavilo šest hrvatskih tvrtki s područja drvnoprerađivačke industrije koje se bave proizvodnjom namještaja.

Na zajedničkom štandu površine 150 m², u paviljonu 5.1, na štandu A-060 i B-061, svoje proizvode predstavili su sljedeći izlagači: Malagić d.o.o., Stribor oprema d.o.o. (sl. 1) i Modo interijer studio d.o.o. (sl. 2).

Također, na navedenom su se sajmu, u sklopu infopulta HGK, putem promidžbenih materijala predstavili i Drvotokarija d.o.o., kao i Grupacija proizvođača namještaja.

Uz potporu navedenih samostalno su nastupili Prima namještaj d.o.o. (sl. 3) i DI GELI d.o.o.

Ove je godine na IMM-u prvi put samostalno izlagala i tvrtka Kvadra. Kvadra, hrvatski dizajnerski brand ojastučenog namještaja na sajmu je uistinu pomaknuo granice interesa međunarodne industrije namještaja. Prezentiranjem svoje prve kolekcije na međunarodno tržište Kvadra je prepoznata po kvaliteti i inovativnom dizajnu proizvoda. Nije slučajno što je direktor Kvadre g. Tomislav Knezović sa svojim poslovnim timom odabrao upravo IMM kao mjesto za izlaganje svojega novog branda, kao i za pokretanje izvoza svoje kolekcije ojastučenog namještaja (sl. 4 – 9). Prema pokazateljima i dojmovima sa sajma – uspio je u naumu!

Nove narudžbe koje pristižu u tvrtku postavljaju Kvadru na mjesto prve hrvatske tvrtke koja u novijoj hrvatskoj povijesti počinje izvoziti finalni ojastučeni proizvod pod vlastitim brandom, noseći potpis hrvatskog dizajna.

Prisjetimo se sajma Ambienta u Zagrebu, kada je Kvadra prvi put prikazala novitete. Kvadrinu kolekciju lansiranu na sajmu u Kölnu čine naslonjači *Elegance*, *Nimble*, *Basic*, *Combo i Easy* (dizajn: kućni dizajnerski tim), sofa *Revolve* (dizajn: Numen/ForUse + Bratović&Borovnjak) i naslonjač te dvosjed *3angle* (dizajn: studio Grupa - Filip Despot, Ivana Pavić, Tihana Gotovuša).

Slika 1. Izložbeni prostor tvrtke Prima namještaj

Slike 2. Prezentacija novih proizvoda tvrtke Kvadra d.o.o.

Tomislav Knezović, direktor tvrtke Kvadra d.o.o., nakon izlaganja iznosi svoje dojmove i ostvarene rezultate: „Glavni razlog zašto smo odlučili izlagati u Kölnu bio je ogroman značaj IMM Köln za globalno tržište namještaja. Nigdje drugdje izloženi raspon ojastučenog namještaja nije veći i ljepši, i nigdje drugdje trendovi nisu tako smisleno i namjenski predočeni. Sajam zasigurno pruža mogućnost pozicioniranja na tržištu na način koji dostojno predstavlja naš proizvod. Mi želimo postavljati trendove drugima, a kvalitetom i dovoljnim prezentacijskim prostorom to možemo i uspjeti!“ Kvadra ima cilj čvrsto se afirmirati i pokazati da Hrvatska proizvodi ne samo dobar dizajn, već da može iznjedriti i vrhunsku kvalitetu, ističe g. Knezović. „Strah od neprihvaćanja hrvatskog branda s kvalitetnim proizvodima bio je neopravdan. Dogodilo se suprotno. Mnogi su mislili da smo skandinavski dizajnerski brand, što nam laska. Kada su saznali da smo iz Hrvatske, nisu na to loše reagirali. Rezultati su nadmašili naša očekivanja. Kvadrina kolekcija doživjela je veliki interes zemalja koje su kolijevke dizajna i kvalitetne izrade poput Danske, Njemačke, Belgije, Francuske i Austrije. Osim europskih zemalja, prihvatile su nas i ostale kulture – Libanon, Izrael, Južna Koreja, Sjeverna Amerika i Australija. Cijela kolekcija Kvadre pobudila je interes među posjetiteljima, premda je sofa *Revolve* bila hit. Dizajneri tog proizvoda oblikovali su i štand kojim se Kvadra suvremeno predstavila međunarodnoj publici.“

Strah da hrvatski dizajn možda neće biti prepoznat na međunarodnom tržištu nestao je već tijekom prezentacije proizvoda na sajmu, kada se pokazalo upravo suprotno: naše stvaralačke dizajnerske snage, u suradnji s kvalitetnim i osviještenim proizvođačima, imaju otvoren put i svoje mjesto na europskom tržištu namještaja. Kao dokaz uspješnosti, proizvod je osvojio *Red dot*, prestižnu nagradu za dizajn, kvalitetu i inovaciju. Iskrene čestitke! Samo naprijed!

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FITZROYA

NAZIVI

Drvo botaničkog roda *Fitzroya cupressoides* pripada botaničkoj porodici *Cupressaceae*. Ostali su nazivi alerce (SAD, Velika Britanija, Francuska, Italija, SR Njemačka), alerze (SR Njemačka), Patagonian cypress (Velika Britanija), lahuan (Čile).

NALAZIŠTE

Fitzroya cupressoides uspijeva u Južnoj Americi, na području Čilea, od 39. do 50. stupnja južne geografske širine, te u južnom dijelu Argentine, gdje se na sjevernim dijelovima širi u močvarne nizine, a u južnima prodire u planinska područja s obilnim oborinama, gdje raste u čistim ili mješovitim sastojinama listača i četinjača.

STABLO

Stabla roda *Fitzroya cupressoides* obično su visoka od 30 do 50 metara, dužine čistih debala 20 do 30 metara. Promjer deblovine je od 1 do 3 metara. Stabla vrlo sporo rastu. Dosežu starost veću od 3 600 godina, što taj rod čini drugom najstarijom živućom vrstom nakon vrste *Pinus longaeva*. Debla su ravna i cilindrična. Kora stabla je debela i crvenkaste boje, ljušti se u uzdužnim uskim trakama.

DRVO

Makroskopska obilježja

Drvo *Fitzroya cupressoides* četinjača je bez smolenica. Godovi su joj vrlo uski, širine od 1 do 3 milimetara. Kasno je drvo usko i znatno tamnije od ranoga. Prijelaz iz ranoga u kasno drvo je postupan. Srž je u sirovom stanju svijetlo crvenosmeđa, a stajanjem potamni do crvenosmeđe boje, koja često poprimi narančasti ton. Tekstura drva je fina i dekorativna. Žica drva je pravilna.

Mikroskopska obilježja

Aksijalne traheide duge su 1,70...2,40...3,80 milimetara, promjera 13,0...30,0...48,0 mikrometara. Debljina stijenki stanica drva iznosi 1,5...3,0...3,5 mikrometara. Volumni je udio aksijalnih traheida u građi drva oko 86 %. Aksijalni je parenhim difuzno raspoređen. Volumni udio aksijalnog parenhima u građi drva iznosi oko 1 %. Drvni su traci isključivo jednoredni, homocelularni, difuzno rasporedeni. Drvni su traci visoki 1...5...9 stanica, odnosno 60...125...215 mikrometara. Gustoća drvnih trakova iznosi 6...7...9 na mm^2 poprečnog presjeka. Volumni udio drvnih trakova u građi drva iznosi oko 13 %. U poljima ukrštanja između aksijalnih traheida i parenhima drvnih trakova je od 2 do 5 kupresoidnih jažica. Završne stijenke aksijalnoga i radijalnog parenhima imaju nodularne jažice.

Fizikalna svojstva

Gustoća standardno suhog drva, ρ_o	290 ... 340 ... 400 kg/m^3
Gustoća prosušenog drva, $\rho_{12\text{-}15}$	oko 380 kg/m^3
Poroznost	oko 77 %
Radijalno utezanje, β_r	oko 3,8 %
Tangentno utezanje, β_t	oko 5,8 %
Volumno utezanje, β_v	oko 9,8 %

Mehanička svojstva

Čvrstoća na tlak	36,2 ... 40,0 MPa
Čvrstoća na vlak, okomito na vlakanca	2,7 MPa
Čvrstoća na savijanje	61 ... 88 MPa
Modul elastičnosti	oko 8,2 GPa

TEHNOLOŠKA SVOJSTVA

Obradivost

Drvo se dobro obrađuje strojnim i ručnim alatima. Dobro se reže, ljušti, tokari i blanja.

Čavle i vijke drži dobro, predbušenje nije potrebno. Izuzetno se dobro cijepa. Dobro se rezbari. Lako se površinski obrađuje i lijepi.

Sušenje

Dobro se prirodno i umjetno suši.

Trajnost i zaštita

Srž drva vrlo je trajna, otporna na djelovanje gljiva uzročnica truleži i insekata te na atmosferilije. Drvo se smatra vrlo trajnim iako je riječ o četinjači. Premda pisani podaci nisu dostupni, drvo je, prema opisu, permeabilno.

Uporaba

Od 16. stoljeća drvo *Fitzroya cupressoides* vrlo je cijenjeno zbog svoje ljepote i trajnosti. Zato je uveliko upotrebljavano u obliku ploča ili šindre za pročelja zgrada u južnom Čileu. Zbog fine, homogene strukture ot tog crvenkastosmeđeg drva izrađivane su bačve, namještaj, glazbala, olovke i rukotvorine.

Napomena

Zbog velike vrijednosti drva, šume *F. cupressoides* naveliko su iskorištavane i tijekom vremena uništavane. U Argentini je F. cupressoides od 1945. godine zaštićena vrsta, a sječe gotovo nema. Godine 1975. *Fitzroya cupressoides* proglašena je vrstom kojoj prijeti istrebljenje te je uvrštena u popis CITES (Convention on International Trade in Endangered Species) kao drvo čija je međunarodna trgovina zabranjena, a 1976. godine u Čileu je proglašena nacionalnim spomenikom. Donesene mjere i propisi nisu doveli do oporavka vrste F. cupressoides, pa se na svjetskoj razini poduzimaju dodatne akcije kojima je cilj očuvanje postojećih šuma F. cupressoides i njihovo obnavljanje.

Literatura

1. Richter, H. G.; Dallwitz, M. J., 2000: Commercial timbers: descriptions, illustrations, identification, and information retrieval. In English, French, German, Portuguese, and Spanish. Version: 16th April 2006. http://delta-intkey.com'
2. Wagenführ, R.; Scheiber, C., 1974: HOLZATLAS, VEB Fachbuchverlag, Leipzig, 477-478.
3. Woods of the world, 1994, Tree talk, Inc., 431 Pine Street, Burlington, VT 05402
4. http://www.woodworkerssource.com/show_tree_wood.php?wood=Fitzroya%20cupressoides
5. http://www.fpl.fs.fed.us/documnts/TechSheets/Chudnoff/TropAmerican/htmlDocs_tropamerican/Fitzroyacupressoides.html
6. http://www.globaltrees.org/tp_alerce.htm
7. http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/cites.pdf

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