

Relationship between Strength and Density as an Indicator of Sycamore Maple (*Acer pseudoplatanus* L.) Wood Quality

Sedlar, Tomislav¹; Sinković, Tomislav¹; Trajković, Jelena¹; Šefc, Bogoslav¹; Jambreko, Branimir¹; Ištok, Iva¹

¹ Department for Wood Science, Faculty of Forestry, University of Zagreb, Zagreb, Croatia

*Corresponding author: Šefc, Bogoslav; bsefc@sumfak.hr

ABSTRACT

The relationship between strength and density of wood plays important role in application of wood in construction. Available information on technical properties of sycamore maple wood are modest, and science based information on many important technical properties of this wood is missing. Some physical and mechanical properties of sycamore maple wood from Medvednica region were investigated. The relationship between strength and density as an indicator of wood quality was calculated. Wood quality was determined by strength quotient, bending quotient and toughness quotient. Variations of mentioned quotients from pith to bark were investigated. Statistical analysis showed no significant differences in the distribution of quotient values from pith to bark. Quality coefficients were compared to available data on some other wood species.

Key words: Bending quotient, Sycamore maple wood, Strength quotient, Toughness quotient, Wood quality

1. INTRODUCTION

Wood quality is defined as the combination of all wood characteristics that affect the value recovery chain and the serviceability of end products (Zhang, 2003). According to that author, wood density has long been considered the most important wood quality attribute and to a large extent determines the suitability of a species for a specific end use. As well, density is one of the major technical properties of wood. It is relatively easy to determine and is well correlated to many other properties of wood, like strength, stiffness, and performance in use. Some wood quality attributes share a unique link. For example, structural timber needs a high density and strength (Barnett and Jeronimidis, 2003).

Sycamore maple (*Acer pseudoplatanus* L.) is native mainly in the mountainous regions of Southern, South-western, Western, Central and Eastern Europe (Figure 1), with the extreme easterly limit at the Caspian Sea (Krabel and Wolf, 2013).



Figure 1. Distribution map of sycamore maple (*Acer pseudoplatanus* L.) in Europe. (Source: EUFORGEN, 2009, www.euforgen.org).

In many parts of Europe, sycamore maple is considered invasive and exotic species and therefore causing some debate among forests breeders and conservators. Some of them believe that sycamore maple should be eradicated in areas where it threatens the ancient indigenous forests (Rusanen and Myking, 2003). Others speak of great economic value and potential of reforestation with sycamore maple, and it is considered as hardwood species whose value grows in Central Europe (Kleinschmit *et al.*, 2009).

Genetic conservation aims at ensuring continuous survival and adaptability of the target species. These proposed guidelines reflect the view that sycamore is not considered an endangered species. Sycamore has significant potential for forestry, and its use as a timber resource should be promoted (Rusanen and Myking, 2003).

In Europe, 1.7% of the total annual cuttings consist of sycamore maple. Researchers claim that the future area proportion of ash, sycamore maple and wild cherry in Europe will double; therefore the future proportion of sycamore maple harvest could increase remarkably (Thies *et al.*, 2009). According to Kölling and Zimmermann (2007) and Kölling (2007), sycamore maple is regarded as a species that is well adapted to current and also to predicted future climatic conditions in Central Europe. The total wood stock of sycamore maple in Croatia is about 3.3 million m³, which represents 0.81% of the total wood stock. About 2.6 million m³ belongs to state forests, while 0.6 million m³ are private (Hrvatske šume, 2014).

There is a very close correlation between density and the strength characteristics of wood (Kolmann, 1951; Niemz and Sonderegger, 2003), therefore it can be used as an indicator for the primary assessment of mechanical properties (Niemz, 1993; Perelygin, 1965; Vikram *et al.*, 2011).

Available data on physical and mechanical properties of sycamore maple wood is modest, and science based information is missing. It is known that relationship between strength and density of wood plays important role in application of wood in construction (Govorčin *et al.*, 1984). In this article, a relationship between strength and density was used as an indicator of wood quality. Wood quality was determined by strength quotient, bending quotient and toughness quotient. Variations of mentioned quotients from pith to bark were investigated.

A described anticipation of growing quantities of sycamore maple in the near future along with the lack of scientifically formed, confirmed and tested information on the properties of sycamore maple wood and on their radial variation have all led to research presented here. Variations in properties of sycamore maple wood are compared with available data for sycamore maple wood, beech wood, and some other diffuse-porous species.

This article describes research on some physical and mechanical properties of sycamore maple wood, as a basis for determination of quality quotients.

2. MATERIAL AND METHODS

For the purpose of this research, five representative sycamore maple trees from different diameter classes were selected with a method of random samples. The test trees were chosen as representative of the stand according to ISO 3129:1999. Trees were located on mount Medvednica, on its northern slope. This area is a part of “Training and forest research center Zagreb”, which belongs to Faculty of Forestry in Zagreb. Mountain Medvednica represents typical natural habitat with a mild continental climate where sycamore maple grows in community with beech.

After cutting down, one test trunk of 1m length was sawn from each test tree. Length of test trunk started at breast height (1.3 m), downwards to root collar. Afterwards, these 1 m long trunks were sawn into bark to the bark cores approximately 6 cm thick. One core was oriented north-south, and the others from east and west side (*Figure 2*). Cores were then submitted to natural drying on dry and drafted stock. After the cores had dried to a water content of about 12%, highest parts of the cores, which were in the area of the breast height (1.3 m), were sawn

out into rectangular samples of 20 mm × 20 mm × 25 mm. The samples were sawn in the radial direction from the pith to the bark and labelled with markers that indicate from which tree they were sawn, to which side of the world they belong to and the ordinal number from the pith to the bark.

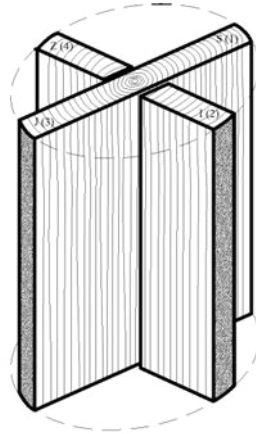


Figure 2. Bark to bark cores (north – south, east and west).

Density was measured according to HRN ISO 3131:1999, compression strength parallel to grain according to HRN D.A1.045-1957 and bending strength according to HRN D.A1.046-1979.

Statistical analysis of the results and their comparison was carried out in specialized statistical program Statistica 8. Statistical analysis has shown the number of measured samples, an average value of certain measured properties as well as their variance. A comparison study of properties of juvenile and mature wood was carried out by Mann-Whitney test.

For the purpose of using wood in construction, relationship between strength and density is considered to be very important. This relationship is referred as the quality coefficient of wood. In this research, the quality of wood was expressed by strength quotient, bending quotient and toughness quotient.

The strength quotient of wood is calculated according to the expression (1):

$$k_s = \frac{\sigma_c}{\rho_{12\%}} \quad (1)$$

where is:

k_s – strength quotient (according to Janka)

σ_c – compression strength parallel to grain (MPa)

$\rho_{12\%}$ – wood density 12% (g/cm^3)

The bending quotient of wood is calculated according to the expression (2):

$$k_b = \frac{\sigma_b}{\rho_{12\%}} \quad (2)$$

where is:

k_b – bending quotient (according to Monnin)

σ_b – bending strength (MPa)

$\rho_{12\%}$ – wood density 12% (g/cm^3)

The toughness quotient of wood is calculated according to the expression (3):

$$k_t = \frac{\sigma_b}{\sigma_c} \quad (3)$$

where is:

k_t – toughness quotient (according to Monnin)

σ_b – bending strength (MPa)

σ_c – compression strength parallel to grain (MPa)

The higher are the quotients, the higher is the coefficient of quality respectively, and the wood is better for use in constructive purposes.

3. RESULTS AND DISCUSSION

Table 1. Comparison of strength quotient of the sycamore maple wood from the Medvednica region with reference sycamore maple wood, beech wood from the same site, beech wood from Gorski kotar, white willow wood and teak wood

Wood species	Density $\rho_{12\%}$ (g/cm ³)	Strength σ_c (MPa)	Strength quotient
Sycamore maple (Sedlar 2015)	0,630	45,5	72,2
Sycamore maple (Wagenführ, 2007)	0,630	49,0	77,8
Sycamore maple (Ehmcke i Grosser, 2014)	0,630	50,0	79,4
Beech (Štajduhar, 1973)	0,740	59,9	80,9
Beech (Govorčin, 1996)	0,660	47,3	71,7
White willow (<i>Salix alba</i> L.)*	0,520	28,0	53,8
Teak (<i>Tectona grandis</i> L.)*	0,630	72,0	114,3

*Legend: $\rho_{12\%}$ – wood density 12%, σ_c – compression strength parallel to grain. * Wagenführ (2007)*

Table 1 shows the comparison of the strength quotient between sycamore maple wood from Medvednica and known data of sycamore maple wood (Wagenführ, 2007; Ehmcke and Grosser, 2014), beech wood from the same site (Štajduhar, 1973), beech wood from Gorski kotar (Govorčin, 1996) and two diffuse porous wood species, white willow and teak.

Mean value of strength quotient of sycamore maple wood from Medvednica varies about 10% from the value of known data of sycamore maple wood (Wagenführ, 2007; Ehmcke and Grosser, 2014) and beech wood from the same site, while it is almost identical to the average value of beech wood from Gorski kotar. Mean value of strength quotient of investigated sycamore maple wood is 35% higher than of the white willow wood, and for about 60% lower than the average value of the teak wood.

Table 2 shows the comparison of bending quotient between sycamore maple wood from Medvednica and known data of sycamore maple wood (Wagenführ, 2007; Ehmcke and Grosser, 2014), beech wood from the same site (Štajduhar, 1973), beech wood from Gorski kotar (Govorčin, 1996) and two diffuse porous wood species, white willow and teak.

Table 2. Comparison of bending quotient of the sycamore maple wood from the Medvednica region with reference sycamore maple wood, beech wood from the same site, beech wood from Gorski kotar, white willow wood and teak wood

Wood species	Density $\rho_{12\%}$ (g/cm ³)	Strength σ_b (MPa)	Bending quotient
Sycamore maple (Sedlar 2015)	0,630	88,5	140,5
Sycamore maple (Wagenführ, 2007)	0,630	95,0	150,8
Sycamore maple (Ehmcke i Grosser, 2014)	0,630	120,0	190,5
Beech (Štajduhar, 1973)	0,740	120,7	163,1
Beech (Govorčin, 1996)	0,660	91,7	138,9
White willow (<i>Salix alba</i> L.)*	0,520	31,0	59,6
Teak (<i>Tectona grandis</i> L.)*	0,630	148,0	234,9

Legend: $\rho_{12\%}$ – wood density 12%, σ_b – bending strength. * Wagenführ (2007)

Mean value of bending quotient of sycamore maple wood from Medvednica varies about 10% from the value of known data of sycamore maple wood (Wagenführ, 2007) and beech wood from the same site, while it is almost identical to the average value of beech wood from Gorski kotar. Mean value of bending quotient of sycamore maple wood (Ehmcke and Grosser, 2014) is about 35% higher than of investigated sycamore maple wood. Mean value of bending quotient of investigated sycamore maple wood is 135% higher than of the white willow wood, and for about 65% lower than the average value of the teak wood.

Table 3. Comparison of toughness quotient of the sycamore maple wood from the Medvednica region with reference sycamore maple wood, beech wood from the same site, beech wood from Gorski kotar, white willow wood and teak wood

Vrsta drva	Strength σ_c (MPa)	Strength σ_b (MPa)	Toughness quotient
Sycamore maple (Sedlar 2015)	88,5	45,5	1,95
Sycamore maple (Wagenführ, 2007)	95,0	49,0	1,94
Sycamore maple (Ehmcke i Grosser, 2014)	120,0	50,0	2,40
Beech (Štajduhar, 1973)	120,7	59,9	2,02
Beech (Govorčin, 1996)	91,7	47,3	1,94
White willow (<i>Salix alba</i> L.)*	31,0	28,0	1,11
Teak (<i>Tectona grandis</i> L.)*	148,0	72,0	2,06

Legend: $\rho_{12\%}$ – wood density 12%, σ_c – compression strength parallel to grain, σ_b – bending strength.
* Wagenführ (2007)

Table 3 shows the comparison of toughness quotient between sycamore maple wood from Medvednica and known data of sycamore maple wood (Wagenführ, 2007; Ehmcke and Grosser, 2014), beech wood from the same site (Štajduhar, 1973), beech wood from Gorski kotar (Govorčin, 1996) and two diffuse porous wood species, white willow and teak.

Mean value of toughness quotient of sycamore maple wood from Medvednica is almost identical to the average value of known data of sycamore maple wood (Wagenfür, 2007), beech wood from the same site, and beech wood from Gorski kotar. Mean value of toughness quotient of sycamore maple wood (Ehmcke and Grosser, 2014) is about 20% higher than of investigated sycamore maple wood. Mean value of toughness quotient of investigated sycamore maple wood is about 75% higher than of the white willow wood and almost identical to the average value of the teak wood.

Table 4 presents mean values of strength quotient (Janka), bending quotient (Monnin), and toughness quotient (Monnin) with statistical indicators based on test results for all trees.

Table 4. Mean values of strength quotient, bending quotient and toughness quotient of all trees.

	Number of samples	Mean value	Minimal value	Maximal value	Standard deviation	Coefficient of variation
						(%)
Strenght quotient	168	72,8	60,6	80,9	4,47	6,14
Bending quotient	157	132,1	99,2	154,9	10,62	8,04
Toughness quotient	157	2,0	1,5	2,4	0,15	7,62

Figures 3, 4 and 5 present the arrangement of quality quotients in radial direction, from pith to bark for all trees together.

By comparing all trees together, the tendency of quality quotients in radial direction, from pith to bark, does not indicate a general conclusion. There is no correlation between quality quotients and distance from pith.

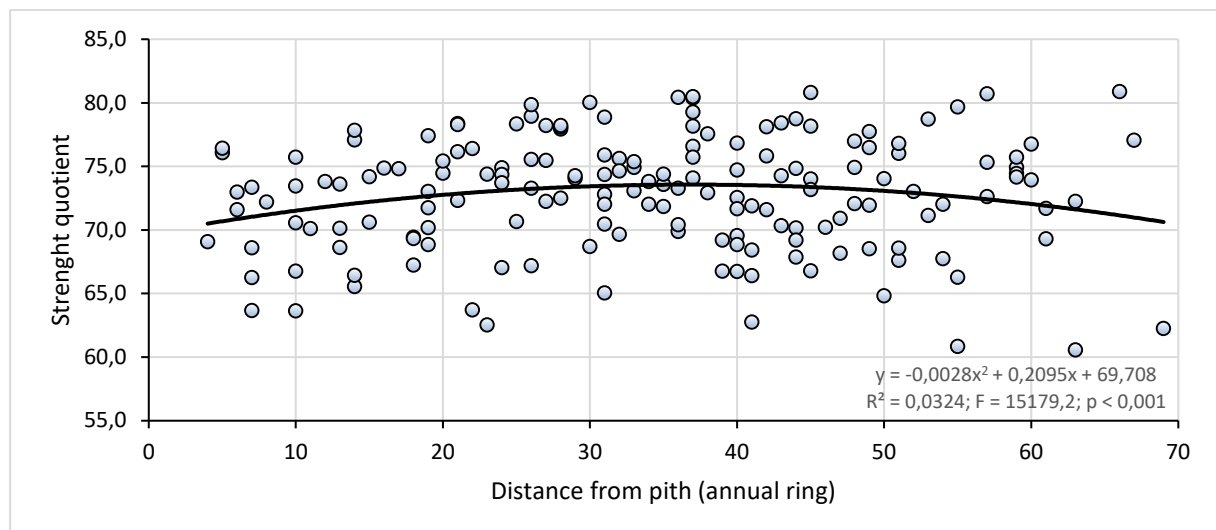


Figure 3. Arrangement of strength quotient in the radial direction of all trees together.

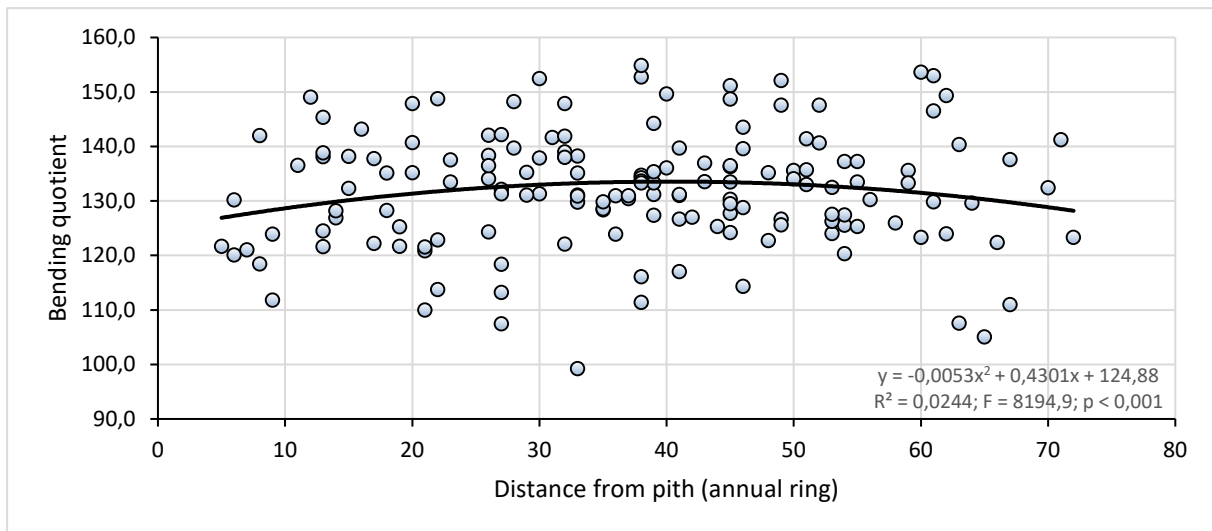


Figure 4. Arrangement of bending quotient in the radial direction of all trees together.

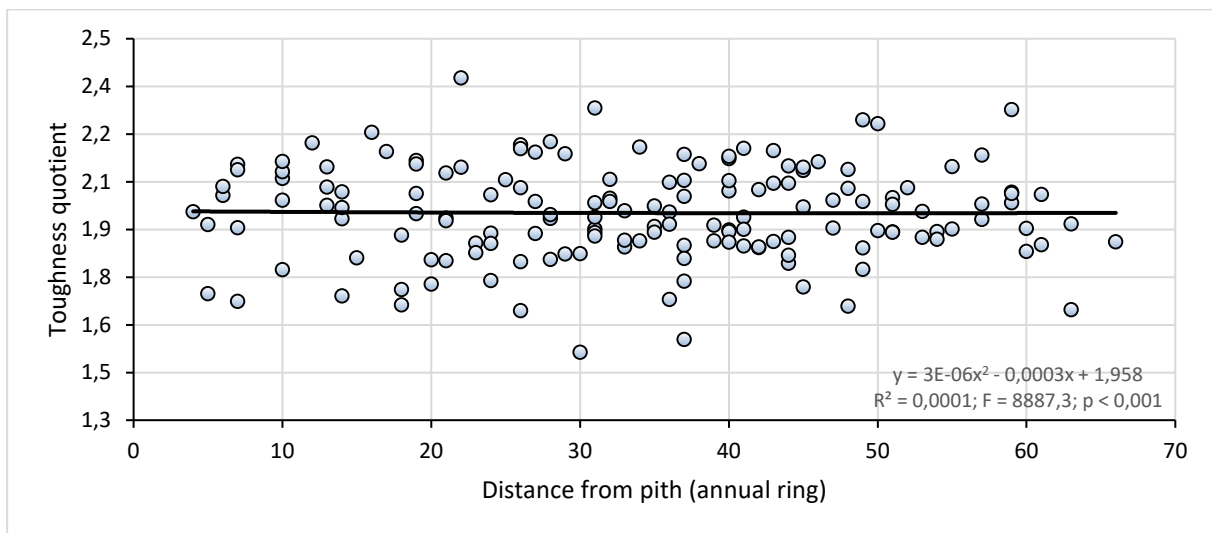


Figure 5 Arrangement of toughness quotient in the radial direction of all trees together.

4. CONCLUSIONS

The difference between quality quotients of investigated sycamore maple wood from Medvednica and known data for sycamore maple wood, beech wood from the same site and beech wood from Gorski kotar are about 10%.

The tendency of quality quotients in radial direction, from pith to bark, does not indicate a general conclusion. There is no correlation between quality quotients and distance from pith.

The results indicate that according to quality quotients, sycamore maple and beech wood could be placed in the same group.

Sycamore maple wood could be used as a potential replacement for beech wood.

REFERENCES

- Barnett, J.R.; Jeronimidis, G. (2003): *Wood Quality and its Biological Basis*. Blackwell Publishing Ltd, Oxford, UK.
- Ehmcke, G.; Grosser, D. (2014): *Das Holz der Eiche – Eigenschaften und Verwendung*. LWF Wissen 75. 53-64.

- Govorčin, S.; Horvat, I.; Bađun, S. (1984): *Fizička i mehanička svojstva bagremovine (Robinia pseudoacacia L.)*. Bilten ZIDI, 12 (5) 44-54.
- Govorčin, S. (1996): *Svojstva juvenilnog i adultnog drva bukovine iz područja Bjelolasice*. Doktorska disertacija. Šumarski fakultet Sveučilišta u Zagrebu.
- Kleinschmit, J.; R. G. Kleinschmit, J. (2009): *Genetics and Tree Breeding*. In Spiecker, Hein, & Makkonen-Spiecker, Valuable Broadleaved Forests in Europe (pp. 45-60). Boston: European Forest Institute: Research report 22.
- Kollmann, F. (1951): *Technologie des Holzes und Holzwerkstoffe 1*. Springer Verlag. Berlin, 1050 pp.
- Kölling, C. (2007): *Klimahüllen für 27 Waldbaumarten*. Allgemeine Forstzeitschrift/Der Wald. 23, 1242 – 1245.
- Kölling, C.; Zimmermann, L. (2007): *Die Anfälligkeit der Wälder Deutschlands gegenüber dem Klimawandel*. Gefahrstoffe. 67, 259 – 268.
- Krabel, D.; Wolf, H. (2013): *Sycamore maple (Acer pseudoplatanus L.)*. In Paques L.E. (ed) Forest tree breeding in Europe. Springer, Netherlands, pp 373–402.
- Niemz, P. (1993): *Physik des Holzes und der Holzwerkstoffe*. DRW-Verlag. Weinbrenner, 243 pp. 32.
- Niemz, P.; Sonderegger, W. (2003): *Untersuchungen zur Korrelation ausgewählter Holzeigenschaften untereinander und mit der Rohdichte unter Verwendung von 103 Holzarten*. Schweizerische Zeitschrift für Forstwesen 154(12): 489-493.
- Perelygin, L.M. (1965): *Wood science. (Náuka o dreve)*. SVTL Bratislava, 448 pp (in Slovak)
- Rusanen, M.; Myking, T. (2003): *EUFROGEN Technical Guidelines for genetic conservation and use for sycamore (Acer pseudoplatanus)*. International Plant Genetic Resources Institute, Rome, Italy. 6 pages.
- Štajduhar, F. (1973): *Prilog istraživanja fizičko-mehaničkih svojstava bukovine u Hrvatskoj*. Drvna industrija 24 (3-4) 43-59.
- Thies, M.; Hein, S.; Spiecker, H. (2009): *Results of a Questionnaire on Management of Valuable Broadleaved Forests in Europe*. In Spiecker, Hein, Makkonen-Spiecker, & Thies, Valuable Broadleaved Forests in Europe (pp. 27-42). Boston: European Forest Institute: Research Report 22.
- Vikram, V.; Cherry, M.; Briggs, D.; Cress, D.W.; Evans, R.; Howe, G.T. (2011): *Stiffness of douglas-fir lumber: Effects of wood properties and genetics*. Canadian Journal of Forest Research 41(6): 1160-1173.
- Wagenführ, R.S. (2007): *Holzatlas*, 6th edn. Fachbuchverlag, Leipzig.
- Zhang, S.Y. (2003): *Wood Quality Attributes and Their Impacts on Wood Utilization*. Proceedings from the XII World Forestry Congress, Quebec City, Canada.
- *** HRN D.A1.045-1957: *Ispitivanje drva – Čvrstoća na tlak paralelno sa smjerom vlaknaca*.
- *** HRN D.A1.046-1979: *Ispitivanje drva – Određivanje statičke čvrstoće na savijanje*.
- *** HRN ISO 3129:1999: *Drvo – Postupci i odrednice pri uzimanju uzoraka za ispitivanje fizikalnih i mehaničkih svojstava*.
- *** HRN ISO 3131:1999: *Drvo – Određivanje gustoće za ispitivanje fizikalnih i mehaničkih svojstava*.
- *** Hrvatske šume, 2014. *Usporedba plana sječe sa izvršenjem sječe od 01.01.2006 do 31.12.2013*.

28th ICWST

International
Conference on
Wood Science
and Technology

IMPLEMENTATION OF WOOD SCIENCE IN WOODWORKING SECTOR

PROCEEDINGS

Zagreb, 7th – 8th of December 2017

University of Zagreb – Faculty of Forestry • Biotechnical Faculty, University of Ljubljana •
Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague •
Forest Products Society • InnovaWood

ORGANISERS

UNIVERSITY OF ZAGREB - FACULTY OF FORESTRY
WOOD SCIENCE AND TECHNOLOGY DEPARTMENT, BIOTECHNICAL FACULTY,
UNIVERSITY OF LJUBLJANA
FACULTY OF FORESTRY AND WOOD SCIENCES, CZECH UNIVERSITY OF LIFE
SCIENCES PRAGUE
FOREST PRODUCTS SOCIETY
INNOVAWOOD

IN COLLABORATION WITH

ACADEMY OF FORESTRY
CROATIAN ACADEMY OF ENGINEERING
THE SCIENTIFIC COUNCIL FOR AGRICULTURE AND FORESTRY – CROATIAN
ACADEMY OF SCIENCES AND ARTS
ASSOCIATION OF ENGINEERS OF WOOD TECHNOLOGY
ZAGREB FAIR

SUPPORTED BY

MINISTRY OF SCIENCE AND EDUCATION
MINISTRY OF ECONOMY, ENTREPRENEURSHIP AND CRAFTS
MINISTRY OF AGRICULTURE
CROATIAN CHAMBER OF ENGINEERS OF FORESTRY AND WOOD TECHNOLOGY
CROATIAN CHAMBER OF ECONOMY
ZAGREB COUNTY



Univerza v Ljubljani
Biotehniška fakulteta



FOREST
PRODUCTS
SOCIETY



UNIVERSITY OF ZAGREB - FACULTY OF FORESTRY

WOOD SCIENCE AND TECHNOLOGY DEPARTMENT, BIOTECHNICAL FACULTY, UNIVERSITY OF
LJUBLJANA

FACULTY OF FORESTRY AND WOOD SCIENCES, CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

FOREST PRODUCTS SOCIETY

INNOVAWOOD

28th International Conference on Wood Science and Technology (ICWST)

IMPLEMENTATION OF WOOD SCIENCE IN WOODWORKING
SECTOR

PROCEEDINGS

Zagreb 7th – 8th of December 2017

Disclaimer:

This book of papers compiles the papers and posters presented at the 28th International Conference on Wood Science and Technology (ICWST) ***Implementation of wood science in woodworking sector*** held in Zagreb, Croatia on 7th and 8th December, 2017. The opinions expressed within are those of the authors and not necessarily represent those of the host, the editors and or any institution included in organisation of this conference.

Although all reasonable efforts were made by the organising team to ensure the scientific quality of the contents of these abstracts, the final responsibility for the content therein and in the final conference proceeding remains with the respective authors. The editors accept no responsibility for the information contained in the proceedings. The editors are not responsible for the contents of external websites referred to in this publication.

A CIP catalogue record for this book is available in the Online Catalogue of the National and University Library in Zagreb as 000979682

Publisher:

UNIVERSITY OF ZAGREB - FACULTY OF FORESTRY

Organizers:

UNIVERSITY OF ZAGREB - FACULTY OF FORESTRY
WOOD SCIENCE AND TECHNOLOGY DEPARTMENT, BIOTECHNICAL FACULTY, UNIVERSITY OF
LJUBLJANA
FACULTY OF FORESTRY AND WOOD SCIENCES, CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE
FOREST PRODUCTS SOCIETY
INNOVAWOOD

In collaboration with:

ACADEMY OF FORESTRY
CROATIAN ACADEMY OF ENGINEERING
THE SCIENTIFIC COUNCIL FOR AGRICULTURE AND FORESTRY – CROATIAN
ACADEMY OF SCIENCES AND ARTS
ASSOCIATION OF ENGINEERS OF WOOD TECHNOLOGY
ZAGREB FAIR

Organizing committee:

Professor **Vladimir Andročec**, PhD (Croatia), Academic **Igor Anić**, PhD (Croatia), Professor **Marian Babiak**, PhD (Slovakia), **Nada Banek**, BSc (Croatia), Professor **Mario Božić**, PhD (Croatia), **Luka Burilović**, BSc (Croatia), **Mariano Perez Campos**, PhD (Spain), Associated Professor **Beata Fabisiak**, PhD (Poland), **Ivica Francetić**, MSc-(Croatia), Professor **Milan Gaff**, PhD (Czech Republic), Professor **Ivica Grbac**, PhD (Croatia), Associated Professor **Miha Humar**, PhD (Slovenia), Professor **Borche Iliev**, PhD (Macedonia), **Iva Ištok**, PhD (Croatia), Professor **Vladimir Jambreković**, PhD (Croatia), Associated Professor **Vassil Jivkov**, PhD (Bulgaria), Academic **Slavko Matić**, PhD (Croatia), Professor **Sergej Medved**, PhD (Slovenia), Professor **Milan Oršanić**, PhD (Croatia), **Ivana Perić**, PhD (Croatia), Assistant Professor **Andreja Pirc Barčič**, PhD (Croatia), Professor **Tomislav Poršinsky**, PhD (Croatia), **Scott Springmier** (SAD), **Dina Tomšić**, PhD (Croatia), **Silvija Zec**, BSc (Croatia), Assistant Professor **Vjekoslav Živković**, PhD (Croatia), Assistant Professor **Ivica Župčić**, PhD (Croatia)

Editors:

Assistant Professor **Ivica Župčić**, PhD
Assistant Professor **Vjekoslav Živković**, PhD
Josip Miklečić, PhD

Technical editor:

Josip Miklečić, PhD

Assistant to Technical editor:

Ms Dubravka Cvetan

Cover photo:

Assistant Professor **Danijela Domljan**, PhD

Programme committee and reviewers:

Assistant Professor **Christian Brischke**, PhD (Germany), Professor **Andrija Bogner**, PhD (Croatia), Assistant Professor **Danijela Domljan**, PhD (Croatia), Professor **Milan Gaff**, PhD (Czech Republic), Professor **Ivica Grbac**, PhD (Croatia), Assistant Professor **Marin Hasan**, PhD (Croatia), Associated Professor **Miha Humar**, PhD (Slovenia), Professor **Mark Irle**, PhD (Belgium), Professor **Vladimir Jambreković**, PhD (Croatia), Professor **Vlatka Jirouš-Rajković**, PhD (Croatia), Professor **Boris Ljuljka**, PhD (Croatia), **Josip Miklečić**, PhD (Croatia), Professor **Stjepan Pervan**, PhD (Croatia), **Peter Rademacher**, PhD (Hungary), Professor **Andreas Rapp**, PhD (Germany), Professor **Milan Šernek**, PhD (Slovenia), **Nikola Španić**, PhD (Croatia), Assistant Professor **Vjekoslav Živković**, PhD (Croatia), Assistant Professor **Ivica Župčić**, PhD (Croatia)

EDITION

300 copies

ISBN: 978-953-292-053-6

FOREWORD

Continuous changes on international market open up new horizons and opportunities, and the new strategies adopted by Europe and the world bring new concepts that need to be adapted and followed. This concept seeks increased social cohesion, striking with the harmful effects of climate change, nature preservation and the creation of a healthy environment. At the same time, creative potentials are open to new knowledge and innovative processes whose primary objective is to adapt to the needs of customers and the environment.

One of the activities carried out in recent years in order to preserve and stimulate rational utilization of raw material is certainly the traditional international scientific conference AMBIENTA. During its continuous sequence in the last 27 years it has become a platform for meeting and networking among scientists, teachers, researchers, students and professionals. In the year 2015 this conference has grown into an international conference on wood science and technology (ICWST), and from last year it became a two-day event, hosted by the Faculty of Forestry of the University in Zagreb.

This year's conference, the second in a row held under the title "*The implementation of science in the woodworking sector*" aims to ensure a multidisciplinary forum where all the participants have the opportunity to present and discuss innovations, trends and practical challenges they have faced in the world of wood science and technology, but also in relation to other materials, technologies, design and other related topics whose aim is to upgrade the wood industry.

We hope that this year's conference will contribute to awareness raising about the significance of wood as an irreplaceable natural raw material, and that the application of scientific research has a positive impact on the wood sector as well as any user of wood.

Assistant Professor Ivica Župčić, PhD

CONTENTS

1. Timothy Young INDUSTRY 4.0 – Pragmatic Algorithms, Information Quality and Relational Databases	1
2. Tetsuya Inagaki; Moe Kashima; Satoru Tsuchikawa Estimation of Wood Density, Moisture Content and Fiber Orientation by THz Time Domain Spectroscopy	3
3. Hikaru Kobori; Sakura Ichijo; Naoki Okano; Yoichi Kojima; Shigehiko Suzuki The Effect of Dry Thermal Treatment on the Vibrational Characteristics of Wood	7
4. V. Sierra Sánchez; M. de Luque Ripoll; M. Álvarez San Millán; S. Pérez Mazarío; P. García Espina; Luis de Luque Ripoll NIRWOOD: an EU Innovation Project to Determine Species and Geographical Origin of Timber using NIR Spectrometry	15
5. Ahmet Can; İsmail Özlüsoylu; Wojciech Grzeskowiak; Eser Sözen Improvement of Fire Performance of Impregnated Wood with Copper Based Chemicals	21
6. Miljenko Klarić; Velimir Nikić; Stjepan Pervan Subfossil Waterlogged Oak-wood (Abonos) Moisture Content Estimation by Electrical Resistance Method	29
7. Hajri Haska; Bajram Kullolli; Hajri Ismaili; Eneida Haska Traditional Ways Using of Wood and Forest Products in Housings and in Daily Livelihoods in Albania Populations/Communities	37
8. Ivan Žulj; Ivica Župčić; Kristijan Radmanović; Ivica Grbac; Valentino Slivar Temperature as an Important Factor in Rotary Welding of Wood	43
9. Nikola Španić; Vladimir Jambreković; Kristijan Radmanović; Goran Mihulja; Jaroslav Kljak Effect of Tartaric Acid Addition to Catalyst on Curing Behaviour of Urea-Formaldehyde Resin	51
10. Ivana Perić, Tomislav Grladinović, Jože Kropivšek, Krešimir Greger Relationship between Entrepreneurial Competencies and Firm Performance: A Study on Furniture Manufacturing SMEs in Croatia	59
11. Fabiana Chipaia; Claudia Urbinati; Patricia Dos Santos; Alisson Reis Identification of Diagnostic Anatomical Features in Ten Species of Sapindales Occurring in the Brazilian Amazon	65
12. Ignacio Urbán Martínez; Ernesto Gutiérrez Tejón; Oscar Santaclara Estévez; Esther Merlo Sánchez Optimization of Juglans sp. Wood Processing from Sustainable Plantations' thinning, Wood Profitability and Final Product Quality	79
13. Branimir Šafran; Matija Jug; Kristijan Radmanović; Igor Đukić; Daniel Kramar; Stjepan Risović Analysis of the Raw Material Properties in the Agro-wood Pellets Production	81
14. Tomislav Sedlar; Tomislav Sinković; Jelena Trajković; Bogoslav Šefc; Branimir Jambreković; Iva Ištok Relationship between Strength and Density as an Indicator of Sycamore Maple (<i>Acer pseudoplatanus</i> L.) Wood Quality	93
15. Tomislav Sinković; Branimir Jambreković; Bogoslav Šefc; Iva Ištok; Filip Veselčić; Tomislav Sedlar Some Physical and Mechanical Properties of White Poplar (<i>Populus alba</i> L.) Wood Grown in Varaždin Region	101
16. Anka Ozana Čavlović; Matija Jug; Andrija Novosel The Efficiency of Exhaust System in the Wooden Floor Production: A Case study	107
17. Ahmet Can; Cengiz Temiz; Hüseyin Sivrikaya Surface Characterization of some Woods Exposed to Accelerated Weathering	115
18. Ahmet Can; Hüseyin Sivrikaya Effect of Water Repellents on the Surface Characterisation of Scots pine (<i>Pinus sylvestris</i>) Exposed to Accelerated and Outdoor Weathering	125
19. Marin Hasan; Adriana Hasan; Gordana Orešković; Branimir Jambreković; Suzana Antolović Contribution to the Optimisation of Esterification of Beech Wood by Citric Acid	135
20. Milan Gaff; Marián Babiak; František Kačík; Veronika Vondrova; Danijela Domljan Bendability of Thermally Modified Oak (<i>Quercus robur</i> F.)	143

21. Reza Hosseinpourpia; Stergios Adamopoulos; Carsten Mai; Venla Hemmilä	153
Effect of Bio-Based Additives on Physico-Mechanical Properties of Medium Density Fibreboards	
22. Sergej Medved; Jože Resnik; Vladimir Jambreković; Nikola Španić; Alan Antonović	159
Image and FT-IR Analysis of Blended Particles	
23. Marina Jajcinovic; Wolfgang Johann Fischer; Ulrich Hirn; Wolfgang Bauer	165
Influence of Relative Humidity on the Strength of Hardwood and Softwood Pulp Fibres and Fibre to Fibre Joints	
24 Juraj Stanešić; Tomislav Podvorec; Alan Antonović	175
Influence of Black Poplar Wood Particle Size (<i>Populus nigra</i> L.) on Content and Properties of Bio-oil	
25. Liubov Kozak; Pavlo Bekhta; Ján Sedliačik; Ján Iždinský	183
Influence of Veneering on the Properties of Lightweight Particleboards with Expanded Polystyrene	
26. Łukasz Krzyżaniak; Jerzy Smardzewski	191
Modeling of Externally Invisible Cabinet Furniture Joints	
27. Jiří Tauber; Zdeněk Holouš; Miroslav Kozák; Sarah Szökeová	199
Trends in the Production and Design of Upholstered Furniture	
28. Boris Iliev; Danijela Domljan	207
Comparison between Preschool Tables used in Kindergartens in Croatia, Macedonia and Bulgaria	
29. Zoran Vlaović; Karla Seleš; Ivica Grbac; Ivan Žulj; Danijela Domljan	215
Comfort of Cervical Pillow with Polyurethane Coil Springs	
30. Alena Sobotková; Milan Šimek; Danijela Domljan	223
Furniture Design for the Entrance Hall	
31. Sarah Szökeová; Miroslav Kozák; Milan Šimek	229
Product Line Safari	
32. Roy Damary; Natalia Pryadilina; Sergey Zalesov; Anton Opletaev	237
Outdoor Wooden Furniture as a Component of an overall Municipal Project: “Green City	
33. Franciska Klanfar; Jerzy Smardzewski; Danijela Domljan	243
Management of the Project of Traditional Estate Adaptation into Object of Village Tourism	
34. Marko Dušak	251
Improvements to the Production Management System of Wood-processing in Small and Medium Enterprises	