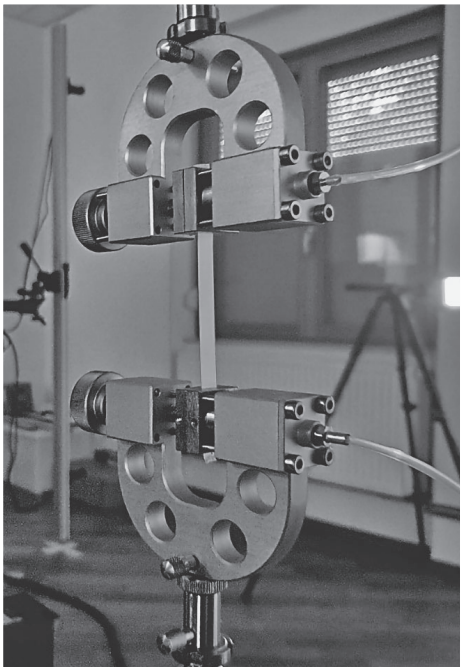
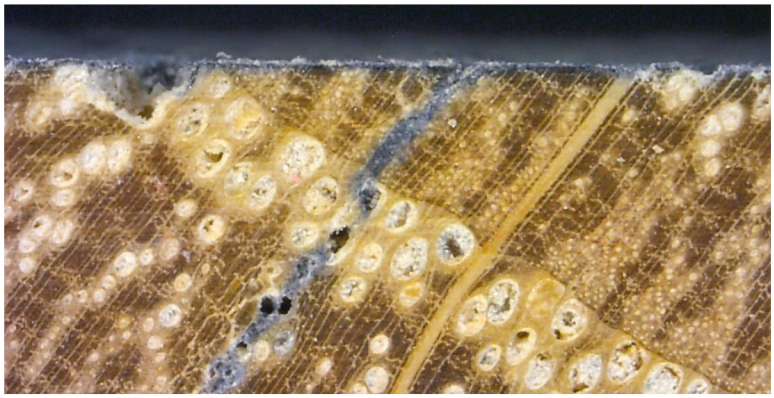
ICWST 2025

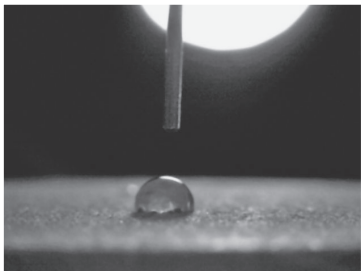
33rd International Conference on Wood Science and Technology

Zagreb, 4th - 5th December 2025

Unleashing the Potential of Wood-Based Materials







BOOK OF ABSTRACTS

UNIVERSITY OF LJUBLJANA
BF Biotechnical Faculty
Department of Wood Science and Technology

Ss. Cyril and Methodius University in Skopje
FACULTY OF DESIGN AND TECHNOLOGY OF FURNITURE AND INTERIOR – SKOPJE

FACULTY OF FOREST INDUSTRY
UNIVERSITY OF FORESTRY
Sofia Bulgaria

Innovawood
connect share influence

Department of Wood Technology, Faculty of Forestry and Wood Tehnology, University of Zagreb, Croatia
Wood Science and Technology Department, Biotechnical Faculty, University of Ljubljana, Slovenia
Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria
Faculty of Design and Technology of Furniture and Interior, ss. Cyril and Methodius University - Skopje, North Macedonia
InnovaWood, Bruxelles, Belgium

33rd International Conference on Wood Science and Technology (ICWST)

Unleashing the Potential of Wood-Based Materials

BOOK OF ABSTRACTS

Zagreb, 4th - 5th December 2025

Disclaimer: This book of abstracts compiles research presented at the 33rd International Conference on Wood Science and Technology (ICWST) ***Unleashing the potential of wood-based materials*** held in Zagreb, Croatia on 4th and 5th December 2025. 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 abstracts content, the final responsibility for the content therein remains with the respective authors. The editors accept no responsibility for the information contained in the book of abstracts. The editors are not responsible for the contents of external websites referred to in this publication.

The CIP record is available in the national union catalogue of the Bukinet library system under the number 991005913938709366.

ORGANISERS

Department of Wood Technology, Faculty of Forestry and Wood Tehnology, University of Zagreb, Croatia

Wood Science and Technology Department, Biotechnical Faculty, University of Ljubljana, Slovenia

Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria

Faculty of Design and Technology of Furniture and Interior, ss. Cyril and Methodius University - Skopje, North Macedonia

InnovaWood, Bruxelles, Belgium

IN COLLABORATION WITH

Academy of Forestry, Croatia

Croatian Forestry Society

Croatian Academy of Sciences and Arts

Croatian Academy of Engineering

Croatian Chamber of Forestry and Wood Technology Engineers

The Croatian Chamber of Economy

Publisher:
Faculty of Forestry and Wood Technology, University of Zagreb, Croatia

Organizers:
Department of Wood Technology, Faculty of Forestry and Wood Tehnology, University of Zagreb, Croatia
Wood Science and Technology Department, Biotechnical Faculty, University of Ljubljana, Slovenia
Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria
Faculty of Design and Technology of Furniture and Interior, ss. Cyril and Methodius University - Skopje, North Macedonia
InnovaWood, Bruxelles, Belgium

In Collaboration with:
Academy of Forestry, Croatia
Croatian Forestry Society
Croatian Academy of Sciences and Arts
Croatian Academy of Engineering
Croatian Chamber of Forestry and Wood Technology Engineers
The Croatian Chamber of Economy

Editors:
Josip Miklečić
Nikola Španić
Miljenko Klarić

Edition:
150 copies

ISBN 978-953-292-093-2

Foreword

Welcome to the 33rd International Conference on Wood Science and Technology – ICWST 2025, themed "Unleashing the Potential of Wood-Based Materials." It is with great excitement that we delve into a rich tradition that has evolved over the years, connecting experts, researchers, and enthusiasts in the field of wood science and technology. Building upon the success of previous conferences, ICWST 2025 is set to be a catalyst for innovative discussions, collaborations, and breakthroughs in the ever-expanding realm of wood science.

Our conference is honoured to be hosted by esteemed institutions such as the Faculty of Forestry, University of Zagreb; Biotechnical Faculty, University of Ljubljana; Faculty of Design and Technology of Furniture and Interior, ss. Cyril and Methodius University - Skopje; Faculty of Forest Industry, University of Forestry - Sofia, and InnovaWood. This collaborative effort reflects the commitment of diverse scientific communities to the advancement of wood science and its applications.

In the spirit of tradition and progress, ICWST 2025 seeks to create a multidisciplinary platform where the exchange of ideas transcends borders. We anticipate the convergence of scientists and researchers from a variety of backgrounds, fostering an environment conducive to scientific novelty, industrial applicability, and comprehensive syntheses of high-impact subjects.

As we reflect on the achievements of the past, present, and future, ICWST 2025 is proud to unveil a program that encapsulates the essence of wood science. Distinguished speakers will explore a wide range of topics. We are honoured to host renowned experts who will share their insights, contributing to the rich tapestry of wood science discourse.

This year's conference aims to go beyond the realms of wood science and technology, touching upon interconnected topics such as materials, technologies, design, and more. We aspire to raise awareness about the vital role of wood as a natural resource in the bioeconomy, advocating for its use as a green building material in the fight against climate change.

We look forward to a conference filled with intellectual exchange, collaboration, and the exploration of the untapped potential within wood-based materials. May ICWST 2025 be a stepping stone towards a future where the sustainable utilization of wood contributes to the betterment of our world.

Editors

Contents

Modelling of Technological Parameters of CNC Milling of Native Wood Species Based on the Targeted Quality

Adamčík, Lukáš*; Kminiak, Richard; Banski, Adrián[1]

[1] Department of Woodworking, Faculty of Wood Sciences and Technology, Technical university in Zvolen, Zvolen, Slovakia

*Corresponding author: xadamcikl@is.tuzvo.sk

ABSTRACT

The aim of this paper is to create a comprehensive model for selecting technological parameters of CNC milling based on the quality of the created surface. The paper investigates the influence of feed speed and rotational speed in CNC milling on native wood species surface quality (characterized by roughness and waviness parameters). The model created for spruce, oak and beech wood was created from data measured and evaluated with a digital microscope Keyence VHX-7000. Roughness and waviness measurements were supported by additional microscopic surface analysis. The samples were milled with a spiral cutter and within the CNC finishing milling operation. The created polynomial regression models (for Ra and Rk separately) established which combination of feed speed and rotational speed will create a surface with the desired quality for selected type of wood. The main outcome of this paper was the identification of the most optimal combinations of technological parameters, considering the overall condition of the native wood species surface.

Key words: CNC milling, surface roughness, surface waviness, native wood, digital microscope

Douglas-fir versus Norway Spruce: Xylogenesis and Growth Stability under Climatic Stress

Balzano, Angela*; Merela, Maks; Krže, Luka; Žigon, Jure; Čufar, Katarina; Straže, Aleš; Krapež, Daša; Zajc, Anže[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Corresponding author: angela.balzano@bf.uni-lj.si

ABSTRACT

Climate change and the increasing occurrence of extreme weather events are threatening the stability of Central European forests, particularly Norway spruce (*Picea abies*), which is highly sensitive to drought and temperature extremes. Douglas-fir (*Pseudotsuga menziesii*), in contrast, has been recognized as a promising alternative species due to its adaptability and strong growth performance. This study compared seasonal xylogenesis and wood formation dynamics of the two species at a site in Slovenia during the 2024 growing season. Microcore sampling and histological analyses were used to track cambial activity, xylem differentiation, and intra-annual density fluctuations formation. The results revealed notable differences in the timing and duration of cambial activity, as well as in wood structure and stability. While spruce showed greater sensitivity to climatic variability, Douglas-fir maintained more consistent growth and a uniform anatomical structure. These findings underscore Douglas-fir's potential to enhance forest resilience and wood quality under future climate scenarios, highlighting its value in sustainable forest management.

Key words: climate change, Douglas-fir (*Pseudotsuga menziesii*), Norway spruce (*Picea abies*), tree growth response, wood formation, xylogenesis

Driftwood as a Material for Making Unique Furniture

Bego, Margarita[1*]; Martinović, Sandra[2]; Lobaš Kukavičić, Iris[1]; Šenjug, Luka[1]

[1] Department of Art and Restoration, University of Dubrovnik, Dubrovnik, Croatia
[2] Department of Wood Technology, Mechanical Engineering Faculty, University of Sarajevo, Bosnia and Herzegovina

*Corresponding author: margarita.bego@unidu.hr

ABSTRACT

This paper explores the potential of using driftwood, collected from the Dubrovnik area (Republic of Croatia), as a sustainable material for furniture design. Building on previous research into its mechanical properties: compressive strength parallel to the grain, bending strength, and modulus of elasticity, this study highlights the reduced processing quality of driftwood due to prolonged exposure to external influences. Within the framework of the "Days of Cultural and Creative Industries" 2024, a unique coffee table was designed and produced at the Department of Art and Restoration, University of Dubrovnik. Special attention was given to aesthetic qualities, particularly the characteristic color changes of driftwood, which were enhanced through surface treatment. The project demonstrates how recycled wood can be carefully selected and applied in modular furniture design, contributing both to sustainable practices and innovative artistic expression.

Key words: driftwood, sustainable materials, furniture design, modular furniture

Conservation and Restoration of the Writing Desk of August Šenoa

Bego, Margarita[1*]; Čavara, Pero[2]

[1] Department of Art and Restoration, University of Dubrovnik, Dubrovnik, Croatia
[2] Škola drvne tehnologije i šumarstva, Zagreb, Croatia

*Corresponding author: margarita.bego@unidu.hr

ABSTRACT

This paper presents the conservation and restoration of the writing desk of August Šenoa, dating from around 1870, crafted by an unknown master and preserved in a private collection. Structural instability was detected during the condition assessment, requiring the dismantling of critical parts. Surface cleaning was followed by the reconstruction of missing wooden elements using the same wood species, identified by comparison with a veneer atlas. Damaged veneer was replaced with matching material, while the final surface treatment consisted of shellac polish, restoring both protective and aesthetic values. The intervention successfully halted deterioration and ensured the valorization of the object for future public presentation within the Šenoa family collection. This case study illustrates the importance of conservation in safeguarding cultural heritage and emphasizes the role of responsible material use in line with circular economy principles.

Key words: conservation, restoration, furniture, August Šenoa, cultural heritage, circular economy

The Use of Shellac as Wood Adhesive

Brus, Maks[1]; Jones, Dennis[2]; Šernek, Milan[1*]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia
[2] Division of Wood Science and Engineering, Department of Engineering sciences and Mathematics, Luleå University of Technology, Skellefteå, Sweden

*Corresponding author: milan.sernek@bf.uni-lj.si

ABSTRACT

Shellac, a natural biopolymer with widespread use in coatings and food packaging, is not typically used in structural applications. The present work investigates its application as a sustainable wood adhesive and establishes optimum processing conditions. Six types of shellac were tested under cold pressing with resulting bond strengths between 7.5-9.5 MPa; SH2 (platinum shellac) was chosen for in-depth characterization. Thermal curing at 175 °C for 60 min remarkably enhanced stability with Tg increasing from 42 °C to 77 °C and mass loss at 200 °C decreasing from 1.55 % to 0.47 %. Crosslinking was confirmed using FTIR through the reduction of hydroxyl content and increase in ester bands. Modelling shear strength development using ABES exhibited excellent fit to the Hill model (R^2 = 0.971). Hot pressing at 175 °C and 200 °C yielded 9.78 MPa and 8.2 MPa in dry conditions (D1), and 3 MPa and 8.4 MPa under occasional moisture (D2), respectively. Pressing at 200 °C, however, resulted in wood degradation with approximately 100 % wood failure. These results point to shellac's potential as a bio-based adhesive for cold pressing and specialized water-free bonding, while emphasizing the necessity for enhancement in moisture resistance and controlled thermal processing.

Key words: ABES, bio-based adhesive, natural adhesive, shellac, thermal curing, wood bonding

Dendrochronology and Wood Science – New Achievements and New Challenges

Čufar, Katarina*; Balzano, Angela; Krapež, Daša; Krže, Luka; Straže, Aleš; Žigon, Jure; Merela, Maks[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Corresponding author: katarina.cufar@bf.uni-lj.si

ABSTRACT

Although dendrochronology is established in many interdisciplinary scientific fields, it fits well into the field of wood science and technology due to its focus on wood, surfaces and microscopy techniques. Dendrochronology requires development and constant improvement of reference chronologies. Recent developments have opened up new areas of research in Slovenia and Croatia, as many reference chronologies for Slovenia can be successfully applied in both countries. When studying the ageing of wood, dendrochronological determination of the age of wood is essential for interpreting changes in its physical and mechanical properties. This is crucial for decisions regarding the maintenance of historical constructions, especially if they have been damaged, for example, by an earthquake. The wood from archaeological sites has been successfully dated using Slovenian chronologies such as Varaždin Stari Grad (1374-1406), Torčec gradić (1263) and Karlovačka Zvijezda (1704) and provided information about structures and past events that would otherwise remain unknown. The study of prehistoric wood, supported by the improved micro CT imaging, radiocarbon analyses and calibration techniques, enabled the dating of 4300 - 6500 years old settlements in Slovenia. Similar investigations are now being successfully conducted in Croatia and at other sites in the region.

Key words: dendrochronology, new methods, radiocarbon, wood science and technology

Opportunities for Using Waste and Mycelium Based Composites in Furniture Design, with a Focus on Outdoor and Temporary Furniture

Daňková, Markéta[1*]; Iždinský, Ján[2]; Jozífek, Miroslav[3]; Sarvašová Kvietková, Monika[1]; Dvořák, Ondřej[1]; Gašparik, Miroslav[1]

[1] Department of Wood Processing and Biomaterials, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, 165 00 Prague, Czech Republic;
[2] Department of Wood Technology, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Zvolen, 96001 Slovakia;
[3] Department of Horticulture, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, 165 00 Prague, Czech Republic

*Corresponding author: dankovam@fld.czu.cz

ABSTRACT

This study investigates three structural configurations of MBC panels made from beech and spruce wood shavings colonized by Ganoderma sessile: (A1) a monolithic panel; (A2) a sandwich formed by fusing two preforms; and (A3) a sandwich incorporating three layers of linen fabric (face–core–face). All samples were stabilized via wet pressing (180 °C, ≤ 8 MPa, 20 min) and subsequently dried (≈ 101–103 °C for 2 h). Evaluated properties included density, water absorption (2 h/24 h), and thickness swelling (2 h/24 h). Pressing improved material cohesion and surface smoothness. The sandwich architecture and linen reinforcement further enhanced planar integrity, cohesion, and handling during growth and post-processing. Despite these improvements, mechanical properties remain below those of particleboards of comparable thickness, and MBCs exhibit higher water uptake and swelling. Nevertheless, the panels retain their shape after re-drying with minimal deformation. The textile surface also enables new aesthetic treatments (dyeing, coatings) without direct contact with the fungal skin. Based on these findings, a design proposal was developed for elements to be used in small furniture (e.g., stools, partitions, flowerpots, bins), where biodegradability is a functional advantage rather than a limitation. After seasonal use, they can naturally decompose into substrate.

Key words: mycelium-based composites, design, density, water absorption, outdoor furniture

Design of a Wooden Portable Office for Engineering Field Work

Domljan, Danijela*; Grabić, Tomislav[1]

[1] Department of Furniture and Wood in Construction, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: ddomljan@sumfak.unizg.hr

ABSTRACT

The topic of this paper is the design and construction of a portable office for field work by users such as wood technologists, builders, architects, technicians, and others. This office would facilitate and accelerate field work while also preventing potential physical discomfort among engineers. The needs of the target group were researched through an online survey in order to propose an innovative design of a portable office that would help these professionals perform their tasks more easily and protect their health. The paper outlines the concept development process, including research into the use of wood in product design and construction.

Key words: body posture, design, engineering field work, musculoskeletal disorders, portable office, wooden materials

Research on Sleep Habits and Influencing Factors

Drača, Maja*; Vlaović, Zoran[1]

[1] Institute of Furniture and Wood in Construction, University of Zagreb Faculty of Forestry and Wood Technology, Zagreb, Croatia

*Corresponding author: majadraca24@gmail.com

ABSTRACT

Sleep quality is shaped by the interaction of multiple factors, with the mattress playing a particularly important role in providing comfort and ergonomic support to the body. Its construction and materials directly affect pressure distribution, spinal alignment, and the subjective feeling of rest. This paper discusses contemporary mattress design solutions and their relationship to ergonomics and health outcomes, while also considering additional elements such as sleep routines and environmental conditions (temperature, light, noise). By analyzing selected scientific literature, the study presents findings on how the combination of mattress ergonomic properties and adapted lifestyle habits can contribute to healthier and higher-quality sleep. The results indicate that the mattress represents a fundamental link between furniture products and user well-being, while routines and environmental factors act as supporting elements. The conclusions emphasize the importance of an interdisciplinary approach and highlight the need to develop objective methods for evaluating mattress comfort in the context of product design, ergonomics, and sleep research.

Key words: comfort, environmental factors, ergonomics, mattress, sleep

Use of Low-grade Feedstock and Torrefaction in the Production of Industrial Wood Pellets

Dujmović, Marin*; Radmanović, Kristijan; Jurčević, Ante; Kalaica, Nikola; Plečko, Marcela; Šafran, Branimir[1]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: mdujmovi@sumfak.unizg.hr

ABSTRACT

Power generation, metallurgy, and other heavy industries are increasingly required to partially or fully replace coal with cleaner biofuel alternatives, driven by stricter regulations on CO_2 and greenhouse gas emissions. Wood pellets have proven to be a viable replacement option, offering performance characteristics relatively similar to coal. However, two major challenges limit broader adoption of pellets in industrial settings. First, growing demand for wood pellets reduces the availability of high-quality and ash-free woody biomass as feedstock for pellet production. We deem that such feedstock is not fully necessary for industrial-grade pellets, as heavy industries have robust handling systems and boilers that can tolerate lower quality biomass, in the first-place higher ash content. For that reason, this study introduces up to 20% of lower-grade mixed species wood chips – typically used as fuel in cogeneration plants – into hardwood pellet production, in order to reduce pressure on higher end feedstocks. Second, conventional pellets still fall short of coal in handling and utilization, forcing industries to make substantial capital investments in boiler modifications and pellet storage silos. To address this second shortcoming, we torrefied pellets at various temperatures and residence times. Torrefaction is a thermal treatment that enhances energy density and improves storage stability of pellets, thereby aligning pellet properties more closely with coal and minimizing capital costs for the industries converting from coal to pellets. The results show that torrefaction increased the calorific value of pellets from 18.2 MJ/kg to 21.2 MJ/kg and enabled outside storage by substantially reducing pellet's water absorption. The addition of lower-grade biomass raised ash content from 1.4% to 1.9%, but this remains acceptable for industrial use. However, mechanical durability declined from 94.2% to 87.6% under the most severe torrefaction. Overall, torrefaction improves pellet's compatibility with existing coal infrastructure, while incorporation of lower-grade feedstock does not substantially affect pellet's quality and potentially offers lower production costs and eases pressure on premium biomass. Further work is needed to explore mitigation of torrefaction's negative impact on pellet durability.

Key words: bioenergy, coal replacement, power plant, solid biofuel, thermal treatment, woody biomass

Prediction of Fatigue Life in Spruce Wood Using Resonance Frequency Analysis

Gaberšček Tuta, Gregora*; Fajdiga, Gorazda; Straže, Aleš[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Corresponding author: gregor.gaberscektuta@bf.uni-lj.si

ABSTRACT

An alternative method for predicting the fatigue life of wood was investigated due to the low accuracy of conventional prediction techniques. Damaged material invariably exhibits a lower resonance frequency than undamaged material because of its reduced stiffness. We conducted a low-cycle fatigue test on a single spruce wood specimen and monitored its resonance frequency. The collected data were used to predict fatigue life using between 40 % and 100 % of the monitored data. A Weibull cycle density distribution was applied to the predictions. Consequently, the predicted number of cycles with the highest probability was selected. The measured stiffness reduction in spruce wood was 35 Hz, or 6 %, which is lower than that observed in similar materials. The prediction error decreased monotonically with the amount of resonance frequency data used for fatigue life prediction, reaching its lowest value of 1 % when the full monitored dataset was employed. The proposed fatigue life prediction method demonstrated potential as an alternative to conventional methods. However, it should be further validated with a larger sample size, as fatigue is inherently a statistical phenomenon.

Key words: spruce wood, fatigue life prediction, resonance frequency, weibull distribution

Evaluating Density Homogeneity in Beech Wood (*Fagus sylvatica* L.) Using Semi-Non-Destructive Resistance Drilling

Gačo Jež, Amina*; Humar, Miha[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Corresponding author: amina.gaco.jez@bf.uni-lj.si

ABSTRACT

Wood is one of the most important materials and its quality is of central importance for based industries. Choosing the right wood for specific purposes requires a thorough evaluation of its technological, physical and aesthetic properties. Among the physical properties, wood density is particularly important as it reflects the ratio of mass to volume at a given wood moisture content and strongly influences the properties of wood. Various non-destructive and semi-non-destructive methods have been developed to assess wood quality, including the resistant drilling (resistographic) method. With this method, we can quickly assess the density of the wood and detect internal defects. In this study, we focused on European beech (*Fagus sylvatica* L.), an economically important tree species in Slovenia and the wider region. The research aimed to determine whether there are statistically significant differences in wood density between measurement heights along the trunk and whether the resistograph can effectively detect internal structural defects. The results showed a trend towards increasing density with height, although the differences were not statistically significant, probably due to the small sample size. Nevertheless, the resistograph proved to be a reliable tool for the rapid and minimally invasive detection of density changes and possible internal trunk damage.

Key words: beech, density, *Fagus sylvatica* L., resistograph

Comparative Wood Anatomy of L-34 Clone of Populus Deltoides Raised By Micro- And Macro Propagation Techniques

Gautam, Pallavi

Department of Botany, D.A.V (PG) College, University H.N.B Garhwal University, City Dehradun (State Uttarakhand), Country India

*Corresponding author: pallavi.gautam82@gmail.com

ABSTRACT

Populus deltoides, commonly referred to as eastern cottonwood or cottonwood poplar, is a tree species belonging to the Salicaceae family. It is native to North America, thriving throughout the eastern, central, and south western regions of the United States, as well as the southernmost parts of eastern Canada and eastern Mexico. Since, its wood has high timber and fiber value for industrial applications; it has commercial significance as well. This wood is used in packing cases for fruits and other food stuffs, it also hold an excellent promise as a source of fiber for various grades of paper-fine paper, packing papers and news prints. *P. deltoides* has been found to be one of the best species for intercropping of agriculture and horticulture crops. The wood has environmental benefits in terms of one of the best species intercropping of agriculture and horticulture crops. This paper attempts to investigate the comparison of wood anatomical properties of *Populus deltoides* raised by micro- and macro propagation techniques. For this study three ramets (replications), each from macro- and micro-propagated plantation of L-34 clone of *Populus deltoides* located in the hilly region of Shivalik range of Himalayas, Uttarakhand. The findings highlighted detailed analysis of the anatomical features of *Populus deltoides* wood, comparing specimens raised through micro and macro-propagation. The study carries importance to bring out the genetical, environmental, Methodological Consistency, Stress Response and Quality Assessment of the given species which can be crucial for light wood and paper industry at large.

Key words: wood anatomy, macro and macro-propagation, *Populus*, genetical, wood and paper industry

Sustainable Utilization of Low-Quality Wood in the Slovenian Bio-Economy: A Case Study on Wood Transport Packaging

Gornik Bučar, Dominika*; Kropivšek, Jože[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Corresponding author: Dominika.gornik@bf.uni-lj.si

ABSTRACT

The amount of low-quality wood is expected to increase in the future, especially as a result of climate change, making it essential to develop and activate various utilization pathways that are in line with the principles of sustainability. Wood packaging already provides such pathway, as it offers medium to high added value, promotes employment in rural areas and embodies the principles of the circular economy through reuse, repair, and material recycling. In Slovenia's forest-based bioeconomy, wood packaging is an important segment, especially in value chains that use lower quality wood and residues. In 2022, almost a fifth of harvested logs in Slovenia was used for wood packaging, with flat pallets being the predominant product. Despite this potential, the value chain is still fragmented and insufficiently documented. There is a lack of adequate infrastructure for repair and recycling. This lack poses a challenge when it comes to meeting upcoming EU regulations, which require a 70% share of reusable wood packaging by 2040. To reach its full potential, Slovenia needs to strengthen logistics and repair systems, invest in digitalization, and improve data collection and the policy framework. Promoting this value chain is crucial to support the transition to a sustainable and resilient bioeconomy.

Key words: low quality wood, sustainability, wood packaging, reuse, recycling

Novel Methodological Approach in Assessing Bond Strength of Edge Bands

Gržan, Tomislav; Domljan, Danijela; Vlaović, Zoran; Župčić, Ivica; Mihulja, Goran[1*]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Coresponding author: gmihulja@sumfak.unizg.hr

ABSTRACT

The durability and quality of furniture products strongly depend on the adhesion of edge bandings applied to wood-based panels, making reliable testing methods essential for evaluating adhesive performance. This study aimed to develop and validate a methodology for assessing bond strength of edge bandings using pull-off and shear tests, based on HRN EN ISO 4624:2023 and ISO 6238:2018, adapted to method development. Experiments were performed on melamine-faced particleboards edge-banded with ABS using hot melt ethylene vinyl acetate (EVA) adhesives and edge band with laser-activated glue (Laser R.T. 1/23 mm). Shear tests were conducted on two fracture surfaces, while pull-off tests were carried out on two testing areas corresponding to the detachment device: a larger one with a steel mushroom-shaped pad, including band edges, and a smaller one with a dolly. Specimens were conditioned under controlled climate and tested with a universal testing machine. Results showed clear differences in bond strength depending on adhesive type and application method. Pull-off tests were more sensitive to adhesion variations, while larger testing areas ensured more stable results and easier preparation. PUR adhesive with laser activation achieved the highest bond strength. Differences between methods were also observed in sample preparation, susceptibility to errors, and result fluctuation. The proposed methodology provides a practical guideline for adhesive selection and reliable evaluation of edge band adhesion.

Key words: adhesive bond strength, edge band, edge-banding, pull-off test, shear test

Research on the Specific Cutting Energy of CO_2 Laser Beam Interaction with Solid Wood and Plywood

Halim, Engindzhan; Gochev, Zhivko*; Vitchev, Pavlin[1]

[1] Department of Woodworking Machines, Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria

*Corresponding author: zhivkog@ltu.bg

ABSTRACT

This paper presents the results of experimental and theoretical studies on the specific energy for laser cutting of solid wood and plywood samples using a ZnSe lens with focal length F = 50.8 mm and focal position on the material surface. The studies were conducted on a CO_2 laser machine, model AEON MIRA 9, at three levels of laser beam power and feed rate variation.

The linear relationship between the weight of material vaporized by the laser beam, the total amount of energy and their relationship with the specific cutting energy represented as a linear equation was investigated using MS Excel and the Data Analysis module, which included a linear regression procedure.

Based on this, a comparison is made between the experimentally obtained results and the theoretically determined ones, and relevant conclusions and recommendations are formulated.

Key words: CO_2 laser, solid wood, plywood, laser cutting, specific energy

Application of Lasers in the Woodworking and Furniture Industry in Bulgaria

Halim, Engindzhan

Department of Woodworking Machines, Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria

Corresponding author: e_halim@ltu.bg

ABSTRACT

The article discusses the history, development and application of laser technologies in the woodworking and furniture industry in Bulgaria. The manufacturers of lasers and laser equipment in the country are presented. An overview of the past and present of the Laboratory of Laser Technologies at the University of Forestry, which is a pioneer in Bulgaria in the application of CO_2 lasers for wood processing and wood-based materials (WBM, is presented. A part of the scientific research and practical work of the laboratory is presented, outlining the directions for its future development.

Key words: lasers, laser beam, laser technology in Bulgaria, woodworking, furniture industry, applications, University of Forestry

Health Assessment of Wooden Constructions of Old Buildings Damaged in the Earthquake

Hasan, Marin[1]; Hasan, Adriana[2]; Tomić, Zvonimir[3]; Župčić, Ivica[1*]

[1] Department of Wood Technology, University of Zagreb Faculty of Forestry and Wood Technology, Zagreb, Croatia
[2] Adria Wood Solutions j.d.o.o., Dugo Selo, Croatia
[3] Franakustik d.o.o., Zagreb, Croatia

*Contact author: izupcic@sumfak.unizg.hr

ABSTRACT

On May 22, 2020, Zagreb was hit by an earthquake with a magnitude of 5.5 on the Richter scale, causing damage to many buildings, particularly in the older parts of the city. In the aftermath, it was necessary to assess the health and quality of the wooden load-bearing beams in the damaged structures and to provide recommendations for reconstruction and chemical protection if needed.

Biological damage is one of the most significant threats to historic wooden structures, alongside fire, earthquakes, and collapse. It can occur after decades of use and is particularly common after centuries. Xylophagous insects and lignicolous fungi are the primary agents of damage, though they typically affect unused spaces (such as roofs and underfloor areas). The extent of the damage is influenced by factors such as the biological resistance of the wood species and microclimatic conditions (including temperature, moisture presence, leaking roofs, condensation in thermal bridges, and moisture uptake in cold, damp climates).

Assessing the health of the wood involves not only identifying the type and extent of the infestation but also selecting appropriate remediation methods, which requires expertise in wood technology and pathology. This paper presents two case studies of historic buildings in Zagreb, illustrating the most common forms of biological damage and the restoration measures needed to ensure the longevity of these structures.

Key words: biological degradation, high-risk areas, reconstruction, wooden beams, wood health assessment methods, wooden roofing

The Influence of the Fastener Penetration Depth on the Withdrawal Resistance

Hristodorova, Desislava*; Mihailov, Vladimir[1]

[1] Department of Furniture Production, Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria

*Contact author: izupcic@sumfak.unizg.hr

ABSTRACT

As a result of the conducted study, the influence of the penetration depth of staples of type M1 and M2 on the withdrawal resistance in wood species of industrial significance was investigated. The experimental findings allowed for the establishment of clear graphical relationships that illustrate the correlation between staple penetration depth and the corresponding withdrawal resistance values. On the basis of the obtained results, well-substantiated conclusions were derived, which enabled the formulation of specific recommendations directed towards the optimization of the design and manufacturing processes of furniture frame structures. These recommendations are intended to enhance the efficiency of wood raw material utilization and to ensure the appropriate selection of staple type for the assembly of such structures in industrial production.

Key words: joints by staples, furniture frame, staple withdrawal resistance

Design and Construction of a Wood–Metal Dining Furniture Set Using Partially Recycled Materials

Ištvanić, Josip; Pervan, Dario*; Vondra, Mislav; Jurišić, Mario; Antonović, Alan; Klarić, Miljenko[1]

[1] Department of Material technology, Faculty of Forestry and Wood technology, University of Zagreb, Zagreb, Croatia

* Corresponding author: dpervan@sumfak.unizg.hr

ABSTRACT

In modern times, most furniture is discarded after a period of use due to wear, dysfunction, or outdated aesthetic-design features. Another contributing factor is the availability of low-cost, mass-produced furniture, which leads consumers to overlook the potential for restoring or reusing parts of their existing furniture. The aim of this study is to demonstrate how combining old, used furniture with new components made from attractive wood species can produce products that are reused rather than discarded. This approach contributes to environmental protection by reducing waste, turning it into material for everyday use. For the construction of a table top, rowan wood (*Sorbus aucuparia* L.) was used, while the seat and backrest of the chair were made from common walnut wood (*Juglans regia* L.). The study also includes technical drawings of the table and chair to illustrate the construction assembly and provide clear insight into the materials used and their dimensions.

Key words: dining set, European walnut (*Juglans regia* L.), recycled materials, rowan wood (*Sorbus aucuparia* L.), wood-metal combination.

Shear Strength of Reinforced Plywood

Jakimovska Popovska, Violeta*; Iliev, Borche[1]

[1] Faculty of design and technologies of furniture and interior-Skopje, SS. Cyril and Methodius University in Skopje, Republic of N. Macedonia

*Corresponding author: jakimovska@fdtme.ukim.edu.mk

ABSTRACT

The aim of this research is to study the shear strength of beech plywood reinforced with non-wood materials in its structure, such as fiberglass and cotton fabrics pre-impregnated with alcohol-soluble phenol-formaldehyde resin (fiberglass prepreg and cotton prepreg). The same resin was used for veneer bonding. The thickness of the veneers used in plywood structure was 1.5 and 1.85 mm. Eight experimental reinforced plywood models were made, four of them reinforced with fiberglass prepreg and the other four with cotton prepreg. The reinforcement was made by inserting certain numbers of sheets of fiberglass/cotton prepreg into the different adhesive layers of the plywood structure. One comparing model of plywood without reinforcement was made. Plywood shear strength was tested in dry-conditioned state at 20 °C/65 % relative humidity and after immersion of the test specimens for 6 hours in boiling water, followed by cooling in water at a temperature of (20±3) °C for 2 hours. In all plywood models, the shear strength was tested in the central veneer layer. The results obtained from the shear strength tests are an indicator of increasing the shear strength values by reinforcing the plywood with pre-impregnated cotton and fiberglass fabrics.

Key words: plywood, reinforcement, pre-impregnated, fiberglass fabric, cotton fabric, phenol-formaldehyde resin

Impact of Styrene Monomer Treatment on the Physical Properties of Spruce Wood

Jambreković, Branimir*; Sedlar, Tomislav; Ištok Pandur, Iva; Hasan, Marin[1]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: jakimovska@fdtme.ukim.edu.mk

ABSTRACT

The structure of wood, as a natural bio-polymeric material composed of long-chain molecules, has evolved to fulfill its primary functions in the living tree, namely, providing mechanical support and ensuring the movement of water and nutrients (conductivity). However, the high water content of wood limits its practical applications. Therefore, reducing its affinity for water (hydrophilicity), increasing water-repelling properties (hydrophobicity), and improving durability and technical performance represent both a challenge and a necessity for wood modification. Wood modification refers to the application of physical, chemical, or biological methods to enhance the physical and mechanical properties of sawn timber, veneer, or wood particles. It serves to improve performance, extend the range of applications, and achieve the desired functionality without negative environmental impacts. Spruce samples were collected in the Gorski Kotar region of northwestern Croatia, approximately 50 km east of Rijeka and 130 km west of Zagreb. The modification was carried out using styrene monomer—a small organic molecule—which was incorporated into wood cell walls previously treated with toluene (an organic solvent) through a process known as radical polymerization. This process utilizes reversible addition–fragmentation chain transfer (RAFT), a technique that enables control over polymer growth. The results for dimensional stability show that modification with styrene monomer significantly improves performance, reducing swelling by 91.18% in the longitudinal direction, 81.42% in the radial direction, 74.61% in the tangential direction, and by 78.06% volumetrically.

Key words: spruce, styrene monomer, dimensional stability, hydrophobicity

Influence of the Corner Joints of the Window Frame and Sash on the Final Quality of the Window

Jevtoska, Elena*; Gruevski, Gjorgi; Mihajlovski, Nikola[1]

[1]Faculty of Design and Technologies of Furniture and Interior – Skopje, University of Saint Cyril and Methodius in Skopje, Skopje, Republic of North Macedonia

*Corresponding author: jevtoska@fdtme.ukim.edu.mk

ABSTRACT

The quality of a product is a characteristic that demonstrates how well it meets the needs for which it is intended. Given that, a window purpose is to provide light and desired ventilation to a room, while at the same time protecting the building from external influences such as air permeability, water permeability and wind resistance, we prove that it is of high quality the more it provides us with these conditions. A window as a product is a complex composition of different materials and parts. The different parts of a window include the basic structural elements, filling elements, fitting, and additional accessories.
The basic structural elements of a window are the supporting frame and the window sash. The corner joints of these elements will be the target of research, in terms of how the strength of the joint of the corner segments of windows made of wooden frame, PVC frame or aluminium frame can affect the window's resistance to air permeability, water permeability and wind resistance.

Key words: window, construction carpentry, window profiles, air permeability, water permeability, wind resistance

Preliminary Tribological Analysis of Ti-Based Coatings in Contact with MDF Using Ball-on-Flat Method

Jovanović, Juraj[1*]; Merhar, Miran[2]; Đukić, Igor[1]

[1] Department of Process Engineering, University of Zagreb Faculty of Forestry and Wood Technology, Zagreb, Croatia
[2] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenija

*Corresponding author: jjovanov@sumfak.unizg.hr

ABSTRACT

A preliminary study was conducted to evaluate the friction coefficient of coatings (TiAlSiN, TiB_2, TiN, TiAlN, and TiAlN+WC/C) on highspeed steel (HS) substrate in contact with medium-density fiberboard (MDF). The experiments were performed on samples with both factory-finished and milled surfaces using the ball-on-flat method on a tribotester, with a normal force of 5 N for friction testing and 15 N for wear testing. Wear characteristics were assessed via a confocal microscope. During testing, the formation of fine dust due to MDF wear was observed accumulating in front of the ball, which hindered the expected stabilization of the friction coefficient and affected the test results. The results of the friction coefficient measurements will be presented, showing the lowest friction coefficient for the uncoated substrate and the highest for the TiAlN and TiAlN+WC/C coatings. Based on the measurement results it appears that this method is not the most suitable for solid wood and wood-based materials. Further research is needed to determine appropriate parameters for testing the tribological characteristics of medium-density fiberboard.

Key words: friction coefficient, tool coating, medium-density fiberboard (MDF), ball-on-flat

Analyses of Noise Emissions during Milling and Sawing of Oak Wood and Fir Wood

Jovanović, Juraj[1*]; Blažević, Marija[2]; Đukić, Igor[1]; Jug, Matija[1]; Beljo Lučić, Ružica[1]

[1] Department of Process Engineering, University of Zagreb Faculty of Forestry and Wood Technology, Zagreb, Croatia
[2] Department of Wood Science and Technology, University of Zagreb Faculty of Forestry and Wood Technology, Zagreb, Hrvatska

*Corresponding author: jjovanov@sumfak.unizg.hr

ABSTRACT

The woodworking has numerous hazards from workplace noise, which causes both short-term and long-term health issues, including hearing damage, stress, and reduced concentration. This study analysed noise levels emitted during processing of oak wood and fir wood at table milling machine and circular saw at feed speeds of 6 m/min and 13 m/min, as well as during idle operation. Measurements of the emitted noise level on machines' operator workplace were carried out using a Kimo DB200 sound level meter instrument. Results show that noise levels during wood processing at milling machine and circular saw significantly exceed the permissible limit for an eight-hour exposure. The highest noise level of the circular saw was recorded during oak wood processing (95.069 dB(A)) and the highest noise level of the milling machine was measured during fir wood processing (88.923 dB(A)) at feed speed of 13 m/min. Although oakwood has higher density, contrary to the expectations, a higher noise level was measured when milling fir wood than when milling oak wood. Noise levels of the milling machine (80.106 dB(A)) and circular saw (85.671 dB(A)) during idle operation is above lower and upper warning thresholds, respectively. Implementing protective measures could reduce noise levels significantly, ensuring worker health and enhancing productivity in the woodworking.

Key words: circular saw, noise level, permissible limit, protective measures, table milling machine, woodworking

Comparative Study of the Role of Lignin and Liquefied Wood in Improving the Physical-Mechanical Properties of Pellets

Jurišić, Mario[1*]; Rustan, Filip[2]; Matin, Božidar[1]; Pervan, Dario[1]; Šafran, Branimir[1]; Dujmović, Marin[1]; Antonović, Alan[1]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia
2 Independent researcher, Zagreb, Croatia

*Corresponding author: mjurisic@sumfak.unizg.hr

ABSTRACT

This paper provides a comparative analysis of two studies examining the impact of adding lignin and liquefied wood on the physico-mechanical and energy properties of wood pellets made from pedunculate oak (*Quercus robur* L.) The lignin addition study investigated shares ranging from 0 to 20 %, showing improvements in calorific value and mechanical durability, but also an increase in ash content and reduction in bulk density. Conversely, the liquefied wood study tested additions from 1.25 to 10 %, demonstrating a significant contribution to mixture homogeneity and preservance of pellet quality in accordance with EN-plus A1 class standards. The comparative analysis indicates that lignin contributes to higher energy values, while liquefied wood provides greater flexibility in optimizing the mechanical properties and overall quality of pellets.

Key words: biomass, ash content, mechanical durability, calorific value, *Quercus robur* L.

The Impact of Global Crises on FSC-Certified Wood Industry: Insights from Croatia, Slovenia, and Slovakia

Klarić, Kristina[1*]; Jošt, Matej[2]; Paluš, Hubert[3]; Katarina Remic[2]; Klarić, Miljenko[1]; Grošelj, Petra[2]; Dzian, Michal[3]

[1] Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia
[2] Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia
[3] Faculty of Wood Sciences and Technology, Technical University in Zvolen, Zvolen, Slovakia

*Corresponding author: kklaric@sumfak.unizg.hr

ABSTRACT

This research examines the impact of global crises, including the COVID-19 pandemic and the conflict in Ukraine, on FSC-certified wood-based companies in Croatia, Slovenia and Slovakia. The wood-based industry is crucial to these economies, and FSC certification plays a key role in promoting sustainability and competitiveness in the market. In recent years, these external shocks have disrupted supply chains, changed market demand and impacted production processes. Data were collected through an online survey of FSC certificate holders in Croatia, Slovenia and Slovakia. Statistical analyses using χ^2 tests and Spearman rank correlation were conducted to assess differences in responses across the surveyed markets. The results show that Slovenian companies experienced a smaller negative impact of the COVID-19 pandemic compared to Croatian and Slovak companies. Difficulties in sourcing materials and selling products varied, with challenges being more pronounced in Croatia and Slovakia. Similarly, the impact of the conflict in Ukraine was relatively evenly distributed across countries. The findings provide valuable insights to policy makers and industry stakeholders in developing strategies to enhance economic resilience and sustainability in the timber industry.

Key words: Croatia, FSC certification, global crises, Slovakia, Slovenia, wood industry

Design And Analysis of Corner Assemblies With 3D Printed Elements Intended for Cabinet Furniture

Konsa, Petar*; Prekrat, Silvana[1]

[1] Department for Furniture and Wood Products, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: petarkonsa@gmail.com

ABSTRACT

The objective of this work was to develop an innovative methodology for the optimization of 3D-printed connecting elements designed for carcass furniture made of 12 mm MDF panels, utilizing computer simulations via the Finite Element Method (FEM). The research encompassed six iterative optimization stages (Step 0 to Step 5) and compared the performance of PLA and ABS materials under a 750 N load. Multivariate Analysis of Variance (MANOVA) confirmed that the optimization stage factor has a highly significant effect on the combination of maximum stress and deformation ($p = 0.000019$). Detailed Tukey HSD analysis established that Optimization 4 (hollow element with a 2 mm wall thickness), due to excessive material removal, resulted in statistically the worst performance, showing the highest stress (PLA; 217.3 MPa, ABS; 211.8 MPa) and the largest deformation (ABS; 17.5 mm, PLA; 9.9 mm), thus differing significantly from all other steps. Simultaneously, Optimization 5 (reinforced partition in the panel groove) proved to be the most favorable in terms of stiffness, achieving the lowest deformation (PLA; 1.85 mm). In the material comparison, PLA demonstrated superiority, achieving a statistically significantly lower average deformation (≈ 3.66 mm) compared to ABS (≈ 6.45 mm) ($p = 0.034$), confirming it as the optimal material for maintaining the joint's geometric stability. These results validate that the methodology of iterative optimization based on FEM allows for informed decisions regarding the optimal design and material solution prior to physical production.

Key words: 3D printed joints, polymer materials, FEM analysis, case furniture joints, structural optimization

Improving Adhesion Properties of Wood Surfaces through Plasma Technology

Kotnik, Klemen[1]; Vaněrek, Jan[2]; Šernek, Milan[1*]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia
[2] Faculty of Civil Engineering, Brno University of Technology, Brno, Czech Republic

*Corresponding author: milan.sernek@bf.uni-lj.si

ABSTRACT

Most adhesive systems for structural bonding are designed for softwoods, which can lead to unsuitable joints when bonding hardwoods or combinations of hardwood and softwood species. By combining beech and spruce in a hybrid glulam, the advantages of both types of wood could be utilised and the possibilities for the use of wood in construction could be expanded. However, significant problems can occur with hybrid glulam in delamination tests caused by unfavourable shrinkage and swelling due to different dimensional changes of beech and spruce induced by moisture changes. If adhesion is insufficient, the bonded joints will fail or delaminate, which can lead to catastrophic collapse of structures or structural glulam elements. Since adhesion is a surface phenomenon, special attention must be paid to surface preparation when bonding wood. One focus of this research is the improvement of adhesion through an innovative surface pre-treatment of wood lamellas using plasma technology. The plasma treatment functionalises the wood surfaces and activates the surfaces before bonding. This can lead to increased adhesion and improved properties of the adhesive joints.

Key words: adhesion, beech, bonding, hybrid glulam, plasma treatment, spruce

Determination of Bearing Loading During Longitudinal Milling of Specimens From Scots Pine and Oak

Kovachev, Georgi*; Atanasov, Valentin[1]

[1] Department of Woodworking Machines, Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria

*Corresponding author: g_kovachev@ltu.bg

ABSTRACT

This study presents how some technological factors influence overbearing loading of the cutting mechanism in a woodworking spindle moulder machine. The rotation frequency used for the experiments was 6000 min^{-1} as it is one of the most used in practice for milling machines. Measurements were made at four points in the radial direction. Two of them are located in the upper bearing units and the other two are in the lower bearing units. A universal woodworking spindle moulder machine with a lower position of the working shaft is used for the experiment. This type of machine continues to be very widespread. During the research, attention was paid to some technological factors such as feed speed of the processed material which is from 2m/min to 10m/min, milling width 12 mm and thickness of removed layer 12 mm. Within the experiment scots pine (*Pinus sylvestris*) and oak (*Quercus*) test samples were milled. Two types of wood used to produce various articles.

Key words: woodworking spindle moulder machine, vibration speed, bearings

Analysis of the Efficiency of Furniture Modeling Using Parametric 3D CAD Program

Kristić, Denis*; Prekrat, Silvana[1]

[1] Department for Furniture and Wood Products, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: kristic962@gmail.com

ABSTRACT

This paper examines the limitations of the exact approach to 3D furniture modeling, which, due to repeated manual modifications, increases the risk of errors and extends the modeling process. The study aimed to determine whether a parametric approach can improve efficiency, ensure consistency, and reduce manual interventions during modifications. The analysis included three cabinet variants: V1 (single-door with four shelves), V2 (double-door with four shelves and a drawer), and V3 (double-door with five shelves, a partition, and two drawers). Modeling was carried out in Autodesk Inventor 2023.1 with the Woodwork for Inventor add-in. Both approaches were assessed by measuring the time required for initial modeling, the duration of modifications, and the number of sketches altered. Results showed that the parametric approach reduced initial modeling time by 33.9–46.6 % (V1 from 9:58 to 5:19, V2 from 18:32 to 10:53, V3 from 26:41 to 17:39). Savings during modifications were even greater, reaching 83.5–97 %. Unlike the exact method, which requires changes to each sketch individually, the parametric approach implements adjustments through parameter values.

In conclusion, while it requires careful planning and parameter definition, the parametric approach enables faster modifications and more reliable technical documentation. The exact method remains applicable for simple or unique projects but shows limitations with increasing complexity.

Key words: autodesk inventor, exact modeling, furniture, multibody method, parametric modeling, woodwork for inventor

Thermal Performance of Sustainable Fibre and Particle Based Composites from Recycled Fibres and Particles

Medved, Sergej[1*]; Bartlett, Craig[2]; Elias, Rob[2]; Španić, Nikola[3]; Jambreković, Vladimir[3]; Young M. Timothy[4]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia
[2] MDF Recovery Ltd, Manchester, United Kingdom
[3] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia
[4] School of Natural Resources, Data Science Institute for Machine Learning and AI, The University of Tennessee, Knoxville, United States of America

*Corresponding author: sergej.medved@bf.uni-lj.si

ABSTRACT

Sustainability, a key word in today's society, becomes particularly important when it comes to the recyclability of post-consumer or production waste and sustainable construction. Due to the increasing demand for products made from fresh wood, the recycling of post-consumer wood and wood-based products such as plywood, OSB, particleboard and production residues is becoming increasingly important. For a long time, MDF and HDF boards were neglected when considering recycling, as the morphology of the components after pulping was undesirable. However, the increasing use of MDF and HDF created a new fibre source for fibre-based products, which was realized by implementing innovative and efficient methods for fibre recovery from MDF and HDF. These fibres, were used in the present study where loose-fill insulation boards were investigated, and compared with those prepared from recycled particles for their thermal properties such as thermal insulation, thermal resistance, thermal phase shift, etc. All materials were tested at three different temperatures and three different humidity levels. A strong correlation was found between density, moisture content and thermal properties. The comparison between loose fill insulation from recycled fibres and particles was also determined. The research results support the use of recycled fibres and particles as an innovative, sustainable raw material source for thermal insulation materials for green and sustainable construction.

Key words: loose-fill insulation boards, recycled fibres, recycled particles, thermal insulation

Strength and Weaknesses of some Alternative Adhesives for Particleboard Production

Medved, Sergej[1*]; Kopač, Luka[1]; Zorman, Nejc[1]; Humar, Miha[1]; Lesar, Boštjan[1]; Španić, Nikola[2]; Jambreković, Vladimir[2]; Antonović, Alan[2]; Young M. Timothy[3]; Jones, Dennis[4]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

[2] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

[3] School of Natural Resources, Data Science Institute for Machine Learning and AI, The University of Tennessee, Knoxville, United States of America

[4] Luleå University of Technology, Wood Science and Engineering Division, Skellefteå, Sweden
*Corresponding author: sergej.medved@bf.uni-lj.si

ABSTRACT

For decades, particleboard manufacturers have been looking for an efficient adhesive system to re-place adhesives containing formaldehyde, but the challenge is multifaceted. The first relates to maintaining strength and elasticity, the second to moisture resistance, which must also be similar or better, and the last to the emission of harmful substances (e.g. for-maldehyde, volatile organic compounds, etc.). Several components like imidazole, citric acid and sorbitol have recently been mentioned as an interesting substance with binding capacity. The present research is also focused on evaluating its performance as adhesive for particleboard production. With the intention of optimizing the properties of particleboard produced in the laboratory, an experiment where particles were blended with imidazole or citric acid and sorbitol in 3:1 ratio (w/w) was performed. Although the internal bond strength, flexural strength and modulus of elasticity were lower, the moisture resistance of the boards, when bonded with citric acid/sorbitol mixture, determined by the thickness swelling, was higher compared to the boards bonded with urea-formaldehyde adhesive. In paper strength and weaknesses of used adhesives is presented.

Key words: citric acid, imidazole, mechanical properties particleboard, sorbitol, thickness swelling

Visualization and Replication of Wood Microstructure Using Micro-CT and 3D Printing

Merela, Maks[1*]; Žigon, Jure[1]; Straže, Aleš[1]; Krže, Luka[1]; Balzano, Angela[1]; Rožle Repič[2]; Krapež, Daša[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia,
[2] Slovenian National Building and Civil Engineering Institute, The Department of Materials, Slovenia

*Corresponding author: maks.merela@bf.uni-lj.si

ABSTRACT

X-ray computed microtomography (micro-CT) is a non-destructive imaging technique used for three-dimensional (3D) reconstruction of structures from two-dimensional X-ray projections of the sample. It provides micrometer-scale resolution and reveals internal features that are invisible on the surface. This method has become increasingly important for studying materials, as it enables detailed 3D visualization and analysis without damaging/altering the sample.

In our work, the internal structures of four wood species—fir, pine, beech, and oak—were examined using an Xradia MicroXCT-400 tomograph (Xradia, USA). Each specimen was scanned during a full 360° rotation, acquiring 1601 projections at submicron resolution. The 3D reconstruction of the scanned volume was done in XMReconstructor (Xradia, USA). The datasets were processed with Avizio Fire software (Thermo Fisher Scientific, USA), where filtering, segmentation and visualisation were performed and surface model (.STL) was prepared as well. Based on these reconstructions, 3D models of wood microstructure were generated and printed at a scale of 1:500. Printing was performed using filaments containing 40 % wood particles and 60% biodegradable PLA, highlighting the use of renewable and sustainable materials in the preparation of physical teaching models.

The resulting replicas are precise, cost-effective, and quickly reproducible. They represent advanced teaching tools that allow students and researchers to explore wood anatomy in a tangible way. Such models enhance understanding, encourage hands-on learning, and provide new opportunities for effective knowledge transfer in education.

Key words: educational models, micro-computed tomography, microstructure, µCT, XCT, wood anatomy

The Influence of Varnish on Modulus of Elasticity and Damping in Wooden Musical Instruments

Merhar, Miran*; Pavlič, Matjaž[1]; Albreht, Luka[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenija

*Corresponding author: miran.merhar@bf.uni-lj.si

ABSTRACT

The acoustic response of a wooden musical instrument depends not only on the method and type of excitation, but also on the mechanical properties of the wood, such as elasticity, shear modulus and damping, as well as on the surface protection of the wood, as this can significantly alter the acoustic response of the instrument. The effect of the surface protection depends on the type of varnish, the thickness of the applied layer, the preparation of the surface before application and the penetration depth of the first layer of varnish. The study investigated the effect of the varnish on the acoustic response of wood. First, uncoated thin wood samples were tested to determine their modulus of elasticity and damping, and then the samples were coated with varnish. The acoustic response of the coated samples was then observed over a longer period of time and the modulus of elasticity for different vibration modes was calculated from the spectrum of natural frequencies and the damping from the temporal recording of the free vibration using Wavelet transform method. Based on the measurement results, a model for calculating the equivalent modulus of elasticity of the coated samples was created, which can be used to calculate the equivalent modulus of elasticity of the coated samples over different time ranges. The model used makes it possible to predict the acoustic response of a new wooden instrument and after a longer period of time.

Key words: damping, modulus of elasticity, natural frequency, varnish, Wavelet transform

Some Physical and Mechanical Properties of Atlas Cedar wood from Bulgaria

Mihailov, Vladimir; Hristodorova, Desislava[1*]

[1] Department of Furniture Production, Faculty of Forest Industry, University of Forestry, Sofia, Bulgaria

*Contact author: d.hristodorova@ltu.bg

ABSTRACT

This paper presents experimental results on selected physical and mechanical properties of Atlas cedar (*Cedrus Atlantica* Man.) wood sourced from Bulgaria. The properties investigated include density, static hardness, static bending strength, modulus of elasticity in static bending, shear strength parallel to the fibers, and splitting resistance. The data were statistically analysed to assess variability, and a relationship between bending strength and modulus of elasticity in static bending was established. The results are presented in detailed tables and graphical form, confirming the favorable physical and mechanical characteristics of wood. Comparisons indicate that its mechanical properties are superior to those of other coniferous species commonly found in the region.

Key words: wood, Atlas cedar, *Cedrus Atlantica* Man., physical-mechanical properties

Comparison of Measurements from a Coordinate Measuring Machine and Manual Instruments in Quality Control of Mortise and Tenon Joints

Mihajlovski Nikola*; Gruevski Gjorgi; Jevtoska Elena[1]

[1] Faculty of Design and Technologies of Furniture and Interior-Skopje, Ss. Cyril and Methodius University in Skopje, North Macedonia

*Coresponding author: mihajlovski@fdtme.ukim.edu.mk

ABSTRACT

The development of final wood processing is closely associated with the introduction and application of appropriate measurement methods. The use of measurements is a critical factor for the advancement of technology. Measurement accuracy is an essential aspect of production metrology, significantly influencing the monitoring of tolerances and fits as well as quality control in manufacturing. The precision of measuring dimensions is a vital component of production, and measurements are conducted throughout all technological phases.
As science and technology evolve, measuring devices also advance. Currently, due to their high accuracy and rapid measurement capabilities, coordinate measuring systems are increasingly employed, with coordinate measuring machines (CMM) being the most prevalent. These machines are widely used to assess the dimensional and geometric characteristics of various products.
This paper presents measurements of joint dimensions using a coordinate measuring machine and compares them with measurements obtained from manual instruments commonly utilized in manufacturing. The difference in measurements is statistically significant, indicating that the values obtained with a coordinate measuring machine are 0.49% lower than those from manual instruments.

Key words: mortise and tenon, coordinate measuring machine, measuring instruments

Effect of the Number of Coating Layers on the Resistance of Wood Surface

Miklečić, Josip*; Jirouš-Rajković, Vlatka[1]

[1] Department for Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Coresponding author: jmiklecic@sumfak.unizg.hr

ABSTRACT

The durability of wood surfaces is a critical factor in their performance across architectural, structural, and decorative applications. This study investigated the influence of the number of coating layers on the resistance of wood surfaces to indoor environmental stresses. Research was conducted on oak and beech wood coated with water-borne and solvent base commercial coatings. Surface resistance was evaluated in terms of resistance to cold liquids, impact resistance, scratch resistance and surface hardness. Based on the obtained results, it can be concluded that the type of coating, the number of coating layers and the type of wood affect the resistance of wooden surfaces. Furthermore, water-borne coating showed higher surface hardness than solvent based coating, especially on samples with a higher number of layers. On the other hand, solvent based coating proved to be relatively more resistant to scratches and impacts, although it is less resistant to certain liquids compared to water-borne coating. These results can serve as a guide for future applications of coatings on interior wood products, ensuring long-lasting and more resilient protection of wooden surfaces.

Key words: surface resistance, water-borne coating, solvent base coating, wood finishing

Product Design and Reusable Materials

Nikoljski Panevski, Elena

Faculty of Design and Technology of Furniture and Interiors, Skopje, R. of Macedonia

*Coresponding author: nikoljski@fdtme.edu.mk

ABSTRACT

The aim of this paper is analysis and elaboration of the whole design process including materials and technology used in production of urban furniture. The furniture is intended for the exterior of an urban area (park, square) – furniture for public use. By analyzing the criteria and parameters, furniture was designed to meet the public urban space.
In the process of composition analysis and creating a geometric shape, the hexagon is taken, in order to create the design of the furniture. Four elements are included, bench, bicycle parking lot, a waste bin, ambient lighting.
When designing the functionality, anthropometric and ergonomic standards are taken into account, as well as the choice of materials that meets the furniture requirements for external conditions and climate change.

Key words: reusable concrete, concrete panels, used wood, eco wood coatings, hexagon, triangle, urban equipment.

Economic and Financial Indicators in the Slovenian Wood Industry

Oblak, Leon*; Kitek Kuzman, Manja[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Coresponding author: leon.oblak@bf.uni-lj.si

ABSTRACT

A review of the activity of the Slovenian wood processing industry in 2024 shows that the industry's economy shrank for the second year in a row. Compared to 2023, sales and the number of employees fell by 9% in 2024, profits by more than 10% , and the investment volume by more than 20%. The reasons for the increasingly poor performance are certainly high taxes, more expensive electricity for large consumers, an uncertain international environment, and staff shortages. This article presents the general characteristics of the activity of Slovenian wood companies in 2024, some economic and financial indicators for the last ten years, and the business challenges of the Slovenian wood processing industry.

Key words: business challenges, economic indicators, financial indicators, Slovenian wood processing industry

Bonding Properties of Differently Modified Beech (*Fagus sylvatica* L.) Wood

Obucina, Murco[1]; Ibrisevic, Alen[1*]; Mahmutspahic Eldina[2]; Mihulja, Goran[3]

[1] Department of Wood Technology, , Faculty of Mechanical Engineering, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
[2] Student of Department of Wood Technology, Faculty of Mechanical Engineering, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
[3] Department of Wood Technology, Faculty of Forestry and Wood Technology University of Zagreb, Zagreb, Croatia

*Contact author: ibrisevic@mef.unsa.ba

ABSTRACT

Various technological processes for wood modification were developed with the aim of increasing durability, mechanical properties, and bonding quality. This study aimed to determine the effect of different modifications of wood and the type of adhesive on the bonding characteristics of joints. In accordance with the purpose of the study, samples made from differently modified beech wood (untreated beech, steamed-treated, and heat-treated beech) were bonded with polyvinyl acetate (PVAc) and polyurethane (PUR) adhesives. The bonding strength of joints were measured. An analysis of variance (ANOVA) was performed to evaluate the impact of the type of wood modification and adhesive used on the bonding characteristics of joints. According to the results of this study, bonding wood with PVAC adhesive results in a higher bonding strength of joints by 30 % compared to samples bonded with PUR adhesive and made from untreated and steamed-treated beech. For heat-treated beech wood higher bonding strength (40 %) was obtained when using PUR adhesive. Heat-treated beech had lower values of bonding strength in relation to untreated and steamed-treated beech wood, regardless of the type of adhesive. The highest bonding strength (13.2 MPa) was obtained for steamed beech bonded with PVAC adhesive.

Key words: wood modification, steamed-treated beech, heat-treated beech, polyvinyl acetate adhesive (PVAC), polyurethane adhesive (PUR), bonding strength

Multifunctional PVA Biocomposites Reinforced with Cellulose Nanofibrils and Functionalized by Tannic Acid

Osolnik Urša*, Vek Viljem, Hrovatič Peter, Oven Primož, Humar Miha, Poljanšek Ida[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Contact author: ursa.osolnik@bf.uni-lj.si

ABSTRACT

Biocomposite films based on poly(vinyl alcohol) (PVA) were reinforced with cellulose nanofibrils (CNF) and functionalized with tannic acid (TA) to improve mechanical and biological performance. The films containing CNF, TA or both were prepared by solvent casting and characterised for their structural, thermal and mechanical properties. CNF improved tensile strength and stiffness, while TA provided antioxidant activity and cross-linking. Their combination had a synergistic effect: the three-component films exhibited up to 40 % higher tensile strength than pure PVA. The thermal stability increased, with Tonset rising by ~30 °C and the T_g increasing due to the limited mobility of the polymer chains, while a slight decrease in T_m indicates the formation of cross-links. Water absorption decreased significantly: PVA with 10 % TA absorbed ~90 % less water, and three-component PVA with 10 % CNF and 10 % TA showed an 80 % reduction after one hour. Hydrophobicity was affected, especially for PVA with 2 % CNF and 10 % TA, which had a 20° higher contact angle. These results show that CNF as reinforcing and carrier phase and TA as antioxidant and crosslinker produce multifunctional nanocomposite films with improved mechanical, thermal and biological properties.

Key words: antioxidant activity, biocomposite films, cellulose nanofibrils, poly(vinyl alcohol), tannic acid

Moisture Content Estimation Using Halogen Analyzer on Several Wood Species

Pervan, Dario; Klarić, Miljenko*; Jambreković, Vladimir; Ivanda, Anamaria; Klarić, Kristina; Ištvanić, Josip[1]

[1] Wood Technology Department, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

* Corresponding author: mklaric@sumfak.unizg.hr

ABSTRACT

The moisture content in wood significantly influences its mechanical properties, usability, and suitability for various manufacturing processes. Accurate determination of moisture content is crucial for optimizing product quality in the wood industry. This paper investigates the applicability of halogen moisture analyzer for measuring moisture content in different wood species (beech, ash, cherry, larch, and oak), comparing its performance with the conventional gravimetric method according to the standard HRN EN 13183-1:2008. The study aims to evaluate the practicality of halogen moisture analyzer compared to the traditional gravimetric method, identifying potential advantages for use in industrial wood processing. Additionally, the research seeks to confirm if the sampling method used is suitable and provides reliable results comparable with the gravimetric method.

Key words: halogen moisture analyzer, wood, moisture content, gravimetric method, wood drying

Optimization of Wood Sampling for Moisture Content Determination Using a Halogen Moisture Analyzer in Multilayer Parquet Production

Pervan, Dario; Klarić, Miljenko[1*]; Jambreković, Vladimir; Sabljak, Marin; Klarić, Kristina; Ištvanić, Josip[1]

[1] Wood Technology Department, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

* Corresponding author: mklaric@sumfak.unizg.hr

ABSTRACT

Accurate determination of wood moisture content is a critical factor in the production of multilayer parquet, where dimensional stability and product quality depend on controlled moisture levels. This research aimed to optimize the sampling procedure of spruce wood for reliable determination of moisture content using a halogen moisture meter. Experimental sampling was carried out on sawn spruce intended for the middle layer of three-layer parquet. Three different sample types were prepared – plugs, shavings, and small sticks – and analysed by the halogen moisture method, while reference samples were tested gravimetrically according to HRN EN 13183-1:2008.

Key words: halogen moisture meter, spruce wood, moisture content, gravimetric method, multilayer parquet

MycoWall: Organic Insulation for Future Timber Constructions

Petržela, Benjamín[1*]; Jozífek, Miroslav[2], Hýsek, Štěpán[3]

[1] Department of Wood Processing, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic
[2] Department of Horticulture, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Prague, Czech Republic
[3] Department of Natural Sciences and Sustainable Resources, Institute of Wood Technology and Renewable Materials, BOKU University, Tulln, Austria

*Contact author: petrzela@fld.czu.cz

ABSTRACT

The construction sector requires new insulation materials that reduce environmental impact and contribute to carbon storage. Conventional synthetic insulations are energy-intensive and difficult to recycle, whereas mycelium-based biocomposites (MBB) offer a sustainable bio-based alternative. Cultivated from lignocellulosic substrates bonded by fungal mycelium, they utilise low-value biomass and need no additional adhesive. This study investigates the application of MBB as an insulation material in timber buildings. Tests confirmed promising thermal performance, with a conductivity of 0.076 W/(m·K) achieved using recycled wood and mycelium of Ganoderma sp. fungi. A prototype wall panel was subsequently developed with heat transfer coefficient (U-value) 0.295 W/(m^2·K). The construction concept combines MBB as the core insulation layer with cross-laminated timber (CLT) as the primary load-bearing system. Deciduous wood species (Quercus sp., Fagus sp.) were employed for complementary elements, treated with an innovative protective method. The external layer is designed as a ventilated façade made of oak profiles coated with a transparent finish containing metal oxide nanoparticles and UV stabilisation. The results demonstrate the potential of MBB to serve as an efficient, carbon-storing insulation material and to enhance the sustainability of building envelopes in modern timber architecture.

Key words: mycelium, composite material, insulation, fungi, recycled wood

The Influence of the Hole Diameter of Perforated Samples on the Acoustic Absorption of Wood and Wood Products

Radmanović, Kristijan[1*]; Krhen, Miljenko[2]; Dujmović, Marin[1]; Jurčević, Ante[1]; Šafran, Branimir[1]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia
[2] Department for Basic Natural and Technical Sciences, Faculty of Textile Technology, University of Zagreb, Zagreb, Croatia

*Contact author: kradmanovic@sumfak.unizg.hr

ABSTRACT

Research into the acoustic properties of wood and wood-based products has a long history, however, increasingly stringent technological criteria and market demands, as well as the development of experimental setups, make these studies attractive even today. In this study, the sound absorption coefficients of whole samples of wood and wood-based materials were experimentally determined, as well as the influence of perforation and diameter of perforated holes on the measured values of the absorption coefficient. For the purposes of the study, samples of wood species and products that are commercially frequently used in Croatia were used: pine, oak, fir, chipboard, MDF and OSB. The sample production process was carefully designed and implemented as a unique, purpose-built production sequence developed exclusively for this acoustic study. The testing was conducted using an impedance tube manufactured by Bruel & Kjaer in the frequency range from 50 to 1600 Hz. The results show a positive influence of perforation of 10% on the sound absorption coefficient for all measurement samples, while the influence of perforation diameter depends on the measurement sample.

Key words: sound absorption coefficient, impedance tube, sample perforation, perforation diameter

Evaluation of Processing Time in Primary Sawmilling of Scots Pine (*Pinus sylvestris*) Logs on a Vertical Band Saw

Stamenkoska, Ana Marija[1*]; Temelkova, Anastasija[2]; Zlateski, Goran[1]; Trposki, Zoran[2]; Rabadziski, Branko[1]; Koljozov, Vladimir[2]

[1] Department of Primary Wood Processing, Faculty of Design and Technologies of Furniture and Interior – Skopje, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia
[2] Department of Machines, Energy and Transport, Faculty of Design and Technologies of Furniture and Interior – Skopje, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia

*Contact author: stamenkoska@fdtme.ukim.edu.mk

ABSTRACT

The efficiency of primary wood processing largely depends on the optimal utilization of macines and tools. Beyond the rational use of sawlogs in sawmilling, the profitability and effective operation of sawmill capacities critically rely on the efficient application of primary processing machines. These machines are primarily tasked with transforming logs into semi-finished products, through which logs are converted into sawn timber through the sawing process. Among the most implemented machines for primary processing are band saws. Theese type of primary machines allow individual log sawing, where each log is processed separately according to its dimensions and quality class. In such operations, determining the technological capacity is essential, defined as the volume of logs a machine can process within a given timeframe. A key factor affecting technological capacity is the processing time per log, which represents the cumulative duration of all sawing operations and factors involved in sawing , such as log rotation, number of cuts, log length and other related activities. The processing time can be divided into components dependent on the machine's technological parameters and those influenced by the organization of production within the sawmill. This study presents a detailed analysis of processing times for Scots pine (*Pinus sylvestris*) sawlogs using a vertical band saw.

Key words: band saw, primary processing, processing time, sawlogs, Scots pine, technological capacity.

Innovation as a Fundamental Instrument of Entrepreneurship

Stankevikj Shumanska, Mira[1*]; Nikolovska, Angela[2]; Antovska, Ivana[1]

[1] Faculty of Design and Technologies of Furniture and Interior – Skopje, Ss Cyril and Methodius University in Skopje, North Macedonia
[2] Kara5 Entertejment DOOEL – Skopje, North Macedonia

Corresponding author: stankevik@fdtme.ukim.edu.mk

ABSTRACT

Innovation plays a fundamental role in entrepreneurship and significantly contributes to economic growth, as well as to providing a competitive advantage in the rapidly changing global market. This scientific paper analyses the theoretical aspects of innovation and provides a deeper understanding of its various dimensions, classifications and impact on enterprises. The research focuses on the complex relationship between innovation and business development and explores how different forms and levels of innovation contribute to improving organisational capabilities and achieving sustainable growth. The research results show that innovation is the foundation for businesses that want to maintain their competitive advantage, adapt to market dynamics and ensure long-term success in the digitalised economy.

Key words: innovation, entrepreneurship, competitiveness, business, economy

Curing Kinetics of Urea-Formaldehyde Resin in the Presence of Wood and Non-Wooden Raw Materials for Particleboard Production

Španić, Nikola*; Simon, Marta; Klarić, Miljenko; Lozančić, Nikolina[1]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: nspanic@sumfak.unizg.hr

ABSTRACT

The industrial production of particleboard is increasingly looking for alternative solutions for the basic raw materials needed for boards production. The use of recycled wooden materials is already widespread, with particleboard manufacturers looking for additional non-wooden raw materials that can be used in production. However, the introduction of such materials in furnishes must be carefully planned as non-wooden lignocellulosic materials have different chemical composition and react differently with adhesives, which leads to potential problems in particleboards production. At the physicochemical level, this primarily refers to changes in curing kinetics of commonly used urea-formaldehyde (UF) resin, and thus associated changes in particleboard pressing times. In order to determine the effect that alternative raw materials have on curing kinetics of UF resin, in this research the rice husks and corn cob kernels were used alongside wood. Several mixtures of mentioned raw materials were prepared and mixed with UF resin, and their curing kinetics were determined by means of differential scanning calorimetry (DSC), following with the infrared analysis (FTIR) of cured resins. The results reveal that the introduction of non-wooden particles caused severe changes of the reaction enthalpy of the UF resin curing leading to changes in activation energy also.

Key words: curing kinetics, non-wooden raw materials, particleboard, urea-formaldehyde resin

Mechanical Properties and Free-Formaldehyde Content of Particleboards Made with the Addition of Dyed Wood Chips

Španić, Nikola*; Brglez, Lucija; Stanešić, Juraj[1]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: nspanic@sumfak.unizg.hr

ABSTRACT

Modern trends in interior design are constantly looking for new possibilities of particleboards use, not only as furniture parts but also as continuously visible wall, ceiling and floor coverings. Alongside appropriate aesthetic properties, to be used in aforementioned areas, particleboards must have acceptable physical, mechanical and chemical properties, that is they must be safe to handle, process and in use. One of the possibilities for obtaining appealing aesthetic properties of such materials is wood staining or dyeing prior to their production. Exactly that approach was used in this research where wood chips were dyed prior to single-layer particleboard production and testing. The results of determination of physical and mechanical properties showed that particleboards made with the addition of dyed wood chips had similar properties to those produced from un-treated wood chips. However, it was concluded that the increase in the dyed wood chip contents did not positively affect the examined properties. This is especially noticeable at free formaldehyde contents, where higher loads results with much higher values, above those prescribed by appropriate EN standards.

Key words: particleboards, wood chip dyeing, mechanical properties, free formaldehyde content

Ergonomics of Conservation-Restoration Work: Introduction to Research into the Relationship Between Working Postures, Repetitive Tasks and the Use of Workplace Furniture and Health

Štengl, Mihael[1*]; Vlaović, Zoran[2]

[1] Department of Art and Restoration, University of Dubrovnik, Dubrovnik, Croatia
[2] Institute of Furniture and Wood in Construction, University of Zagreb, Faculty of Forestry and Wood Technology, Zagreb, Croatia

*Corresponding author: mstengl@unidu.hr

ABSTRACT

This paper presents the results of an introductory part of the study on the relationship between working postures, repetitive tasks, and the use of workplace furniture and their impact on health conducted among conservators-restorers through an online survey.
The objective of this study was to investigate the relationship between working postures, repetitive tasks, the use of work furniture, and the occurrence of health problems among conservators-restorers. This research was conducted through a survey of 91 respondents from Croatia and other European countries. The collected data encompassed the participants' field of specialisation, working habits, health status, and the need for and use of workplace furniture, among other factors. This paper focuses only on the analysis of the first part of the survey, which addresses the respondents' basic demographic characteristics, health status, and working habits.
The results of the initial part of the survey indicate that conservators-restorers spend a substantial number of hours in awkward and static postures, and frequently engage in repetitive tasks. Such working conditions are closely associated with a high incidence of occupational diseases, including carpal tunnel syndrome and various musculoskeletal disorders. The findings highlight the necessity of improving ergonomic and occupational conditions in conservation-restoration practices, as well as the importance of greater attention to the health and well-being of professionals in this field.

Key words: conservation-restoration, ergonomics, furniture, musculoskeletal disorders

Analysis of Influential Parameters on the Mechanical Properties of Basalt Mesh-Reinforced Plywood

Talić, Hasan*; Ćehić, Minka[1]

[1] Department of Wood Technology, Faculty of Engineering, University of Bihać, Bihać, Bosnia and Herzegovina

*Corresponding author: hasan.talic@unbi.ba

ABSTRACT

The mechanical properties of plywood, particularly bending strength, are influenced by numerous parameters. Efforts to improve these properties are focused either on the development of new materials or on the enhancement of existing ones, such as plywood. This study investigates plywood reinforced with basalt mesh. To evaluate the significance of various parameters affecting plywood properties, several analytical methods are applied. The paper outlines widely applied tools and methods for quality management in product design and for modeling the structure of plywood. A practical case study illustrates the assessment of selected parameters influencing the bending strength of basalt mesh-reinforced plywood, including the orientation angle of the surface veneer fibers and the number of basalt meshes.

Key words: plywood, basalt, mathematical modeling, quality management, methods

Evaluation of Noise Emissions from a CNC Woodworking Centre under Different Cutting Conditions

Vitchev, Pavlin*; Halim, Engindzhan[1]

[1] Department "Woodworking machines", Faculty of Forestry, University of Forestry, Sofia, Bulgaria

*Corresponding author: p_vitchev@ltu.bg

ABSTRACT

This study experimentally investigates the variation of noise emission levels (LpA) generated during the machining of Scots pine (*Pinus sylvestris* L.) specimens on a CNC machining center, depending on the cutting conditions. The combined effects of tool rotation speed (n), feed rate (Vf), and depth of cut (h) on noise levels were analysed. The influence of each factor on noise emission was assessed. The experimental methodology considers the background noise and the characteristics of the sound field. Specimens were processed individually using two CNC finishing spiral router cutter with identical angular and linear parameters but different cutting geometries. Graphical dependencies illustrating the correlation between the individual factors and their impact on noise levels during machine operation are presented. The results indicate that noise emission levels are significantly affected by these variables, reaching a maximum of LpA = 82 dB(A) at a tool rotation speed of n = 18000 min^{-1} and a feed rate of Vf = 5 m·min-1.

Key words: CNC machining, cutting parameters, noise emission, Scots pine (*Pinus sylvestris* L.), tool rotation speed

Exploring Elastic Properties of Flexible PUR and Latex Foams for Furniture

Vlaović, Zoran*; Vidoni, Nikola; Mihulja, Goran[1]

[1] Institute of Furniture and Wood in Construction, University of Zagreb Faculty of Forestry and Wood Technology, Zagreb, Croatia

*Corresponding author: zvlaovic@sumfak.unizg.hr

ABSTRACT

The problem of furniture comfort is addressed in many ways, but most often using soft polyurethane (PUR) foams or similar materials. To be a good cushioning material, a foam must exhibit good comfort and load-bearing properties. Twelve foam samples of different types, densities, and thicknesses were tested according to ISO 845:2006 and ISO 2439:2008 standards to determine their apparent core density, indentation hardness, compressive deflection coefficient, and hysteresis loss rate. The samples included conventional PUR foams, high resilience (HR) PUR foams, low resilience (visco) PUR foams, latex rubber foams, and a hybrid PUR-latex foam. Results showed that latex foam exhibited the most favourable profile, combining exceptional support with stable recovery and moderate hysteresis loss. The HR and hybrid foams also provided a strong overall performance, whereas conventional PUR foams were inconsistent, with limited support. Viscoelastic foam performed the poorest in terms of resilience and energy efficiency, confirming its role as a specialty material for pressure redistribution rather than support. The findings provide professional users (designers and manufacturers) with insights into the characteristics and qualities of different foams, facilitating their selection for use in seating and lying furniture.

Key words: elastic properties, furniture, ISO 2439, latex foams, polyurethane foams

Challenges in Information Systems Implementation: Financial, Organizational, and Technical Factors

Vukman, Karla*; Perić, Ivana; Pirc Barčić, Andreja; Klarić, Kristina[1]

[1] Department of Production Organization, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: kvukman@sumfak.unizg.hr

ABSTRACT

Implementation of information systems is a key success factor for modern organizations undergoing digital transformation. As organizations increasingly rely on data-driven decision-making and interconnected processes, information systems provide the infrastructure for efficiency, innovation, and competitiveness. Despite clear benefits in optimizing processes and improving competitiveness, implementation projects often encounter three interrelated categories of barriers: financial requirements, organizational resistance, and technical integration challenges. The paper is based on an analysis of recent literature (2015–2025) to identify the most important challenges in information systems implementation. The analysis identifies high initial investments, lack of professional skills, and infrastructure limitations as the most frequently cited barriers. The findings consistently highlight leadership support, investment in education, and gradual implementation as key success factors for overcoming barriers. In the context of SMEs, financial and technical constraints are particularly modulating the effects of new technologies such as the Internet of Things and artificial intelligence. Organizations need integrated strategies that simultaneously address financial, organizational, and technical dimensions. The paper emphasizes the development of organizational change management capabilities as a prerequisite for successful digital transformation, while highlighting the need for holistic approaches that recognize the complex interdependencies between different implementation challenges.

Key words: information system, organizational challenges, financial requirements, technical integration, resistance to change

Challenges and Perspectives of Digital Transformation in the Wood Industry

Vukman, Karla*; Klarić, Kristina; Miklošić, Denis; Crnojević, Jelena; Perić, Ivana[1]

[1] Department of Production Organization, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: kvukman@sumfak.unizg.hr

ABSTRACT

Digital transformation is increasingly viewed not only as a technological shift but as a strategic and organizational process where digital culture and employee readiness play a central role. This paper examines the digital maturity of Croatia's wood industry, comparing survey data collected in 2025 with earlier findings. The analysis reveals changing adoption patterns, particularly regarding ERP/CRM systems, organizational culture, and the integration of sustainability. While traditional barriers such as costs and technical difficulties have diminished, ERP and CRM use has declined, indicating a selective and non-linear digitalization trajectory. The results confirm that Europe's wood industry remains 20–30 years behind more advanced sectors, with ERP systems still underutilized as efficiency drivers. Furthermore, sustainability and risk management have emerged as essential components of the digital agenda. By providing evidence from a post-transition economy, this study highlights the growing importance of digital culture, employee skills, and sustainability in shaping industrial digital transformation.

Key words: digital transformation, wood industry, enterprise resource planning, sustainability, resistance to change

Integrated Life Cycle and Techno-Economic Analysis of Hardwood Cross-Laminated Timber Production in the Eastern United States

Zhao, Jinghan[1]; Wang, Jingxin[1*]; Denes, Levente[2]; Laleicke, Frederik[1]; Peszlen, Ilona[1]

[1] Department of Forest Biomaterials, North Carolina State University, Raleigh, North Carolina, USA
[2] School of Natural Resources and the Environment, West Virginia University, Morgantown, West Virginia, USA

*Corresponding author: jingxin_wang@ncsu.edu

ABSTRACT

Cross-laminated timber (CLT) has been a significant R&D focus in wood products and engineering due to its excellent structural performance, environmental benefits, and broad market potential. While CLT has traditionally been made from softwood, there is growing interest in hardwood CLT due to its performance advantages and opportunities for the value-added application of underutilized hardwood resources. Currently, studies on the environmental impacts and economic viability of hardwood CLT remain in their early stages. This study conducts an integrated life cycle assessment (LCA) and techno-economic analysis (TEA) to evaluate the environmental and economic performance of hardwood CLT production. It quantifies the greenhouse gas emissions associated with producing one cubic meter of hardwood CLT, identifies hotspot processes, and examines the influence of key uncertainty factors such as species variation, transportation distance, and energy sources. The study also calculates the unit production cost, internal rate of return, and minimum selling price. It provides a scientific basis for the optimization and commercialization of hardwood CLT, contributing insights toward its adoption in the green building industry.

Key words: cross-laminated timber, hardwood, life cycle assessment, techno-economic analysis, wood-based construction

Mapping the European Wood Education Community

Zatoń, Patrycja*; Jancke, Oliver; Ustych, Radmila; Kies, Uwe[1]

[1] InnovaWood absl, Brussels, Belgium

*Corresponding author: patrycja.zaton@innovawood.eu

ABSTRACT

The wood education ecosystem in Europe plays a crucial role in training future professionals equipped to meet the demands of a rapidly evolving industry. It encompasses a range of higher education institutions that offer specialised curricula in wood science and technology. The landscape of wood education is diverse, including programs that aim to foster a deep understanding of wood properties, processing techniques, and sustainable practices. These educational efforts are vital for promoting scientific knowledge in wood-related fields and for ensuring that graduates are prepared to take on challenging roles within the wood industry. The commitment to developing skilled professionals is essential for sustaining innovative practices and maintaining competitiveness in a global market.

The objective of the paper is to map the current status of wood education programs across Europe and to identify key areas where improvements are necessary to align educational outcomes with industry requirements. The methodology contained four steps: 1) mapping institutions from studies and databases, 2) scanning of conferences and consortia, 3) scanning of scientific publications, and 4) scanning HE institutions per website search. This study is especially focused on Eastern European institutions, which have been less examined in prior research, thereby contributing valuable insights into a less explored region of the wood education ecosystem.

The mapping of the European wood education community identified 400 wood higher education programmes, including 158 bachelor's (BSc) and 173 master's (MSc) programmes in 154 institutions within two groups. The institutions in the first group that provide BSc, MSc, and/or PhD programs (at least one) with wood as a primary focus, such as "wood technology," "wood engineering," "wood sciences," etc. The second set of institutions offering BSc, MSc, and/or PhD programs where wood is involved in other or broader fields but not the major topic, e.g., "forestry", "furniture design", "architecture", "civil engineering", "sustainable construction", etc.

The assessment highlights critical challenges facing the industry, particularly a skilled labour shortage exacerbated by an ageing workforce. The impending retirement of experienced professionals significantly contributes to a knowledge and skills gap within the industry. This gap hampers the industry's ability to adapt to changing consumer preferences and technological advancements. In conclusion, addressing these workforce challenges through targeted education and training initiatives is crucial for ensuring the sustainability and competitiveness of the European wood industry in the future.

Key words: wood, higher education, study programmes, green and digital transition, wood community, wood education

Correlation Between Characteristics of Growth Increment and Scratching Resistance of Douglas-Fir Wood

Žigon, Jure*; Merela, Maks; Straže, Aleš; Krapež, Daša; Krže, Luka; Balzano, Angela[1]

[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

*Corresponding author: jure.zigon@bf.uni-lj.si

ABSTRACT

This study investigates how the anatomical and micromechanical properties of Douglas fir (*Pseudotsuga menziesii* L.) vary in different radial positions and developmental zones (juvenile wood, adult wood, sapwood and heartwood). Micro-scratch tests were used to determine wood hardness at the microscopic level, which is a sensitive measure of tip penetration resistance. The indented tip penetrated deepest in juvenile wood and sapwood, consistent with thinner cell walls, larger lumens, lower density and higher porosity. In contrast, adult wood and heartwood exhibited greater resistance, reflecting higher density and enhanced mechanical properties. The ratio between growth ring width and penetration depth ($\Delta x/\Delta Pd$) proved to be a useful indicator of changes in porosity and mechanical properties with tree age. Environmental conditions also played a role: higher temperatures and lower precipitation negatively affected radial growth. Statistical analysis confirmed significant correlations between micromechanical properties of wood and the growth conditions of the trees. The findings provide new insights into how growth environment influences Douglas fir wood quality, offering valuable knowledge for forest management and wood processing industry.

Key words: Douglas-fir, growth increment, porosity surface hardness, scratching resistance

Thickness Joining of Solid Wood Using Rotary Welding

Župčić, Ivica; Čatić, Matija; Đukić, Igor; Gržan, Tomislav; Hasan, Marin[1*]

[1] Department of Wood Technology, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

*Corresponding author: jure.zigon@bf.uni-lj.si

ABSTRACT

Wood welding is a relatively new technology for joining wooden elements that offers envi-ronmentally friendly joints and an alternative to classic methods such as wood gluing. There are two main methods of wood welding: vibration and rotational welding. In both methods, friction and pressure result in the formation of a welded joint.
This paper examines the possibilities of thickness joining of solid wood using rotational dowel welding. Based on the results of the research, it can be concluded that the variable hole diameter significantly contributes to increasing the strength of the joint, regardless of the type of dowel. Also, samples with a smooth dowel surface achieve higher joint strengths on average compared to grooved dowel surfaces. The highest mean value of the joint strength was achieved in samples where smooth dowels were welded into holes of variable diameter and is 295.3 MPa.

Key words: rotary welding, thickness joining, dowel, solid wood

Beyond the Surface: Inside Wood Through Advanced 3D Technologies for Teaching and Research

Merela; Maks[1*]

1 Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia

Corresponding author: Maks.Merela@bf.uni-lj.si

ABSTRACT

Advances in 3D imaging and visualization technologies are transforming both the study and teaching of wood science. This plenary lecture will present an integrated approach combining virtual 3D wood collections and micro-CT imaging to explore the internal structure of wood in unprecedented detail. I will showcase our interactive 3D virtual wood collection, which enables students to examine anatomical features, understand wood properties, and engage with material in a more intuitive and immersive way. In parallel, I will demonstrate applications of micro-CT imaging for research purposes, including a case study on dendrochronology applied to a cultural heritage object, highlighting how these technologies reveal hidden structures and support precise scientific analysis. By bridging pedagogical and research applications, this presentation illustrates how advanced visualization tools not only enhance learning but also open new pathways in wood science research. Attendees will gain insight into both the educational and scientific potential of 3D technologies, and how these tools can be used to study wood from the macroscopic to the microscopic scale.

Key words: wood anatomy, microstructure, educational models, micro-computed tomography, µCT, cultural heritage

ISBN 978-953-292-093-2