8TH HARDWOOD CONFERENCE

WITH SPECIAL FOCUS ON "NEW ASPECTS OF HARDWOOD UTILIZATION – FROM SCIENCE TO TECHNOLOGY"

25-26th October 2018
Sopron
Hungary

Hardwood Conference Proceedings

Volume 8

Editors: Róbert Németh, Alfred Teischinger, Peter Rademacher, Miklós Bak

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COST is an EU-funded programme that enables researchers to set up their interdisciplinary research networks in Europe and beyond. The COST Association provides funds for organising conferences, meetings, training schools, short scientific exchanges or other networking activities in a wide range of scientific topics. By creating open spaces where people and ideas can grow, COST Actions unlock the full potential of science.

Now, the 8th Hardwood Conference has the pleasure to be linked with one of the current COST Actions, **FP1407**: Understanding wood modification through an integrated scientific and environmental impact approach (ModWoodLife).

As part of the interaction between this Action and Hardwood Conference, the following presenters have been provided with assistance for their involvement at this conference:

Pavlo Bekhta (Ukraine), Fatima Bouchama (Belgium), Lukas Emmerich (Germany), René Alexander Herrera Diaz (Spain), Edo Kegel (Netherlands), Edgars Kuka (Latvia), Andreja Kutnar, (Slovenia), Rastislav Lagana (Slovakia), Jaka Pečnik (Slovenia), Luigi Todaro (Italy), Nebojša Todorović (Republic of Serbia), Aleš Zeidler (Czech Republic)

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Parallel Session IV.

Parallel Session V.

Parallel Session VI.

Plenary session

Hardwood resources, process chains, challenges and solutions

Alfred Teischinger[1], Christian Huber[2], Christian Hansmann[3]

[1] A-3400 Tulln, Konrad Lorenzstraße 24, University of Natural Resources and Life Sciences (BOKU), alfred.teischinger@boku.ac.at

[2] Same address as above, christian.huber@boku.ac.at

[3] A-3400 Tulln, Konrad Lorenzstraße 24, Competence Centre Wood K plus
c.hansmann@kplus-wood.at

Keywords: Hardwood process chain, value yield, hardwood utilization, material flow

ABSTRACT

In comparison to the softwood production chain, comprising just a few species, the hardwood process chain is characterized by a variety of specific wood species for the various production chains (fig. 1). This creates various logistic challenges in the main mill processes and the side-stream management as well, such as where to allocate wood chips from sawmill processing or how to utilize saw dust and shavings – especially from a mixed species production – other than for energy uses.

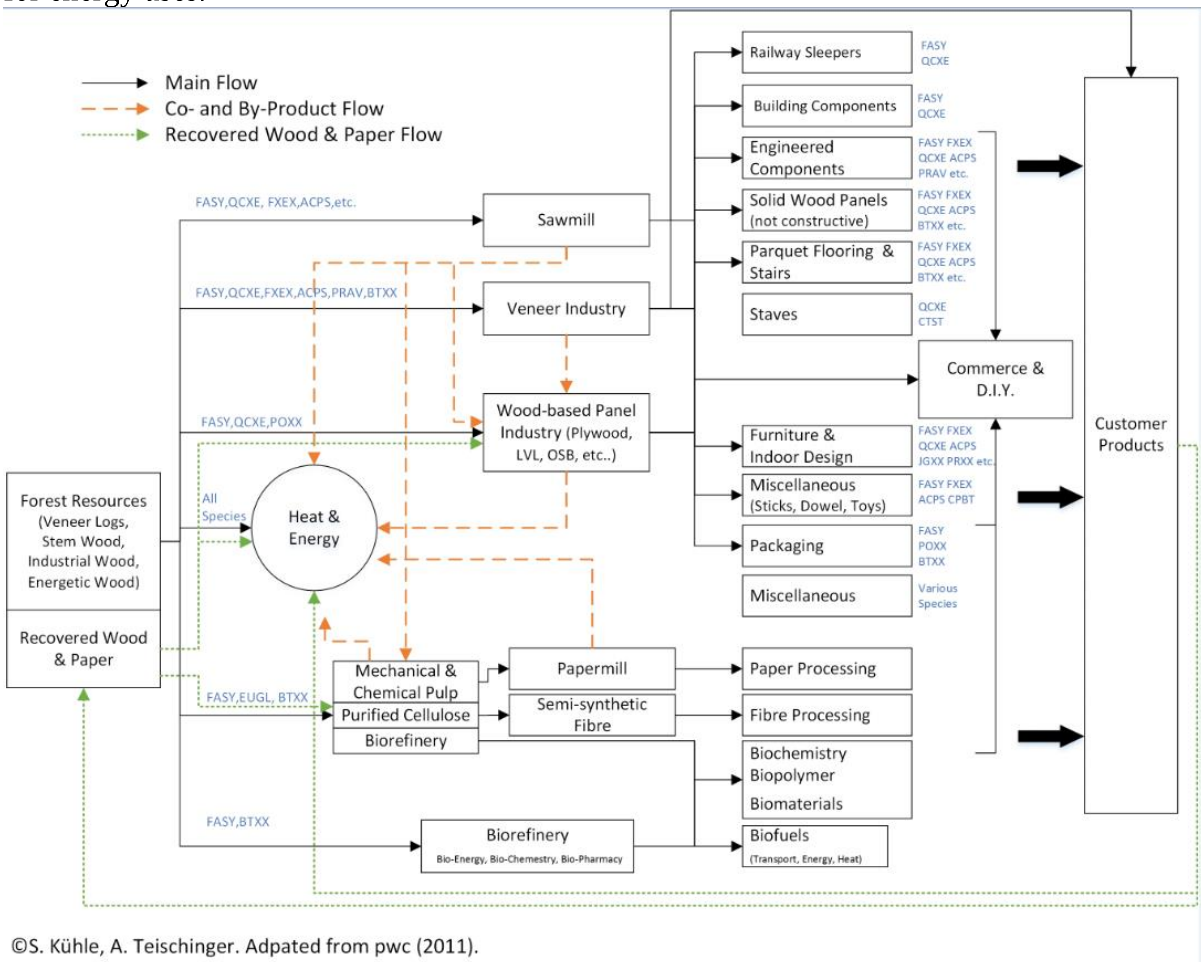

***Figure 1:** Various hardwood process chains including side streams indicating the most dominant species per chain (short code for single wood species according to EN 13556), not fully elaborated*

Within one hardwood species, there might also be big regional differences in properties which command the price and favour a specific application. For example: Oak wood from the Allier region (FR), Rheinland Pfalz (DE) or Tokaj region (HU) is appreciated for barrel making and in general oak from Spessart (DE), Slavonia (CR) and Poland is especially appreciated for the veneer and furniture production (TEISCHINGER 2017). The various regional differences in hardwood properties with respect to specific uses in wood products are well-known by experienced traders and wood procurement managers but there is only an unstructured documentation of such specific knowledge.
A very important feature of hardwood utilization is the different tree morphology compared to softwoods and the different value yield along the tree height as shown in fig. 2.

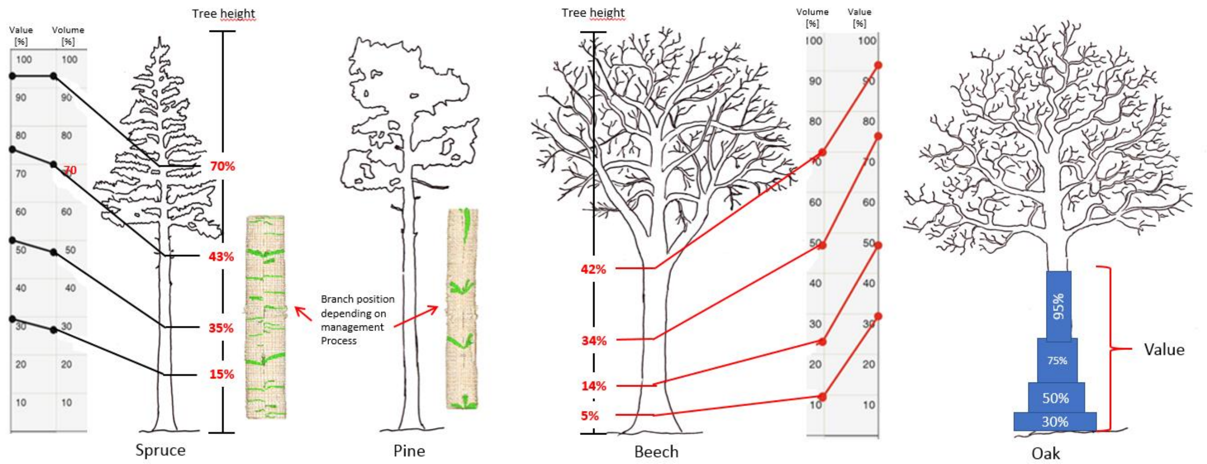

Figure 2: Comparison of tree shape and value yield from selected softwoods and hardwoods

As an example, the very aspects of hardwood utilization are reviewed and summarized by KRACKLER et al. (2010), FNR (2012), WEHRMANN et al. (2015), TEISCHINGER 2017, but apart from the current hardwood utilization concepts, new technologies and products have to be envisaged.

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Wood anatomy - the role of macroscopic and microscopic wood identification against illegal logging

Gerald Koch[1], Immo Heinz[1], Uwe Schmitt[1], Hans-Georg Richter[1]

[1] Thünen Institute of Wood Research, Leuschnerstr. 91, 21031 Hamburg, Germany

gerald.koch@thuenen.de

Keywords: wood identification, wood properties, macroHOLZdata, CITESwoodID

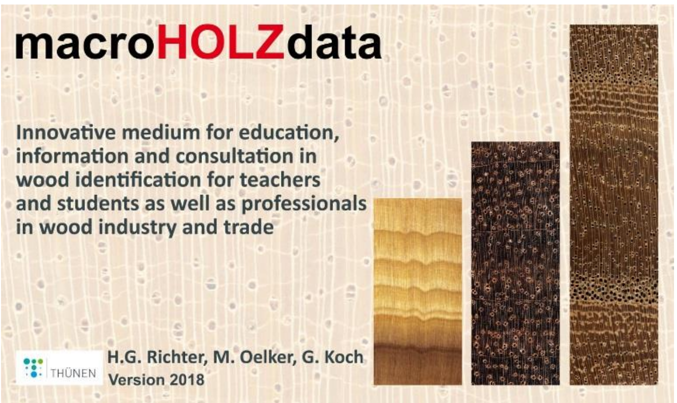
ABSTRACT

Illegal logging is one of the chief causes of worldwide deforestation and, by releasing greenhouse-relevant gasses, contributes to climate change. Moreover, trade with illegal timber and wood products creates market disadvantages for products from sustainable forestry. As a contribution to global forest protection, international laws and timber regulations are enacted, such as the European Timber Regulation (EUTR), and the USA Lacey Act. These regulations prohibit the import and trade of illegally forested wood and require that timber and timber products have to be produced in accordance with the respective national legislation. Controls are based on a due diligence system requiring a correct declaration of the wood species (botanical name) and origin of the timber (KOCH ET AL. 2016). The clear identification of internationally traded timber is also of prime importance in enforcing CITES policies regarding protected species (KOCH ET AL. 2008). Based on inquiries of the UN Office on Drugs and Crime, "rosewood" (*Dalbergia* spp.) accounted for the highest percentage of illicit wildlife seizures by value from 2005 to 2014. In this context, the entire genus *Dalbergia* spp. (about 250 species; except for Brazilian rosewood = *Dalbergia nigra*, which is listed in Appendix I) as well as the three Bubinga species of *Guibourtia demeusei*, *G. pellegriniana*, and *G. tessmannii*, and Kosso (also called African rosewood = *Pterocarpus erinaceus*) were newly listed in CITES Appendix II.

A valuable support to facilitate wood identification of internationally traded and CITES-protected timber based on macroscopic features is already provided by the databases **macroHOLZdata** and **CITESwoodID** (RICHTER ET AL. 2003, KOCH ET AL. 2011) developed in the DELTA-INTKEY-System (Fig. 1). Both databases have recently been updated and adapted to the trade of lesser-known hardwoods, with focus on Asian timbers imported into the EU (e.g. Machang = *Mangifera* spp., Paulownia = *Paulownia* spp., or Schima = *Schima wallichii*) and the newly listed CITES wood species (e.g. *Dalbergia* spp.).

In detail, the databases **macroHOLZdata** and **CITESwoodID** offer:

- an interactive identification of 130 important trade timbers (macroHOLZdata) and 44 CITES-listed timbers (CITESwoodID) based on macroscopic features which can be observed with the unaided eye or with a hand lens,
- numerous high quality illustrations of wood characters and timbers alike featuring transverse and longitudinal surfaces,
- a database with pertinent information on wood properties, processing, and utilization (macroHOLZdata)
- a textbook with definitions, explanations, procedures, etc. for most features used in the description.



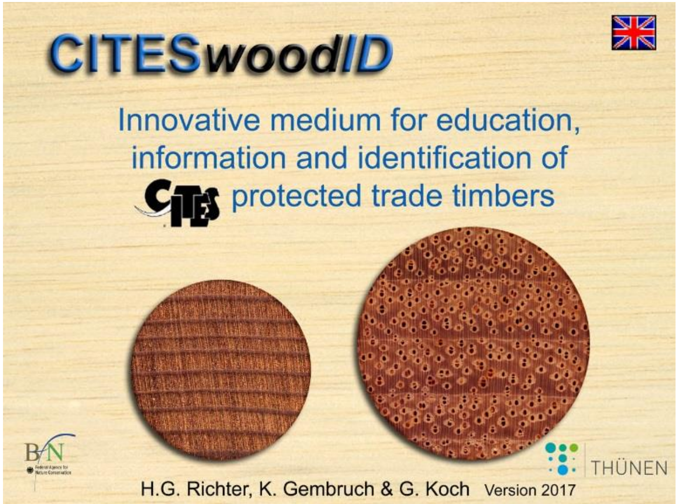


***Figure 1:** Computer-aided wood identification and description using the databases macroHOLZdata and CITESwoodID*

The databases are primarily designed for all institutions, companies and individuals involved in international trade and control of wood and wood products. It is also well suited for education and advanced training of students and in the timber industry.

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Wood modification – different processes and their use in Europe

Dick Sandberg & Dennis Jones

Wood Science and Engineering, Luleå University of Technology, 931 86 SKELLEFTEÅ, Sweden,
dick.sandberg@ltu.se, dennis.jones@ltu.se

Keywords: Acetylation, thermal modification, furfurylation, silicate, silanes

ABSTRACT

Nowadays, wood modification is referred to as a process used to improve the physical, mechanical, or aesthetic properties of sawn timber, veneer or wood particles used in the production of wood composites. Though many aspects of these treatments are known, the fundamental influence of the process on product performance, the environment, and end of life scenarios remain relatively unknown. It is essential to integrate interactive assessment of process parameters, developed product properties, and environmental impacts. To optimize modification processing to minimize environmental impacts, much more information must be gathered about all process related factors affecting the environment.
Wood modification represents an assortment of innovative processes currently being adopted in the wood protection sector or are at different stage of development (Fig. 1). These processes produces a material that can be disposed at the end of a product´s life cycle without presenting any environmental hazards greater than those that are associated with the disposal of unmodified wood.

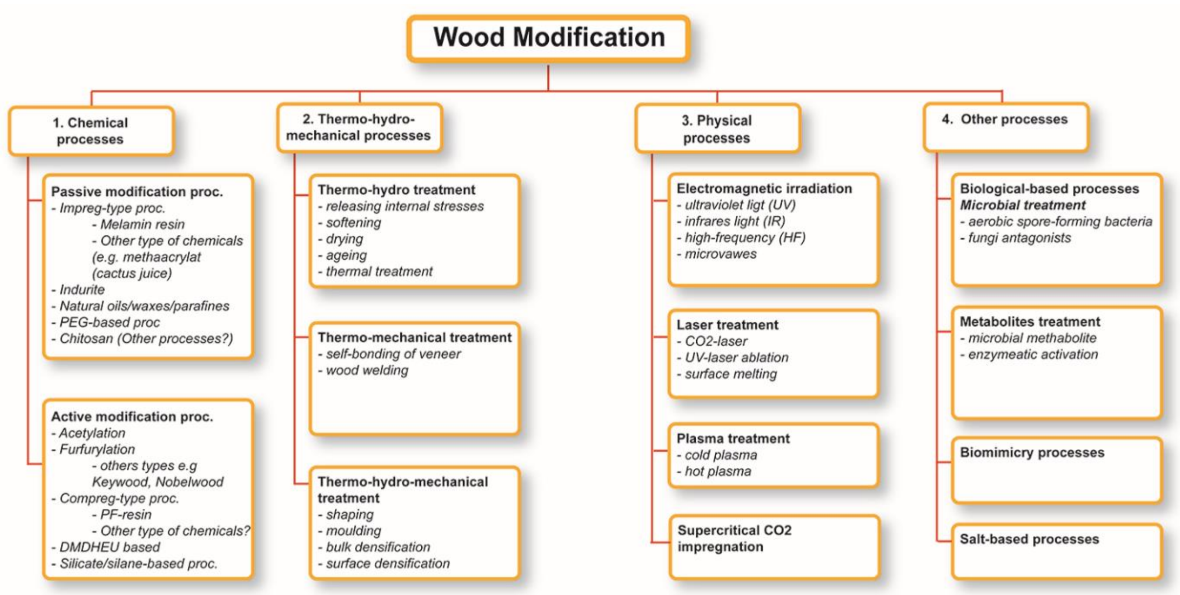

Figure 1: A diagram of the various wood modification processes

A recent task within COST FP1407 was to re-evaluate the current status of wood modification across the member countries, tasks previously undertaken within COST Actions E22 and E37 respectively and reported in several papers within several of the previous European Conferences on Wood Modification (ECWM). As a part of COST Action FP1407, it was decided to review the production values across Europe, whereby each national production level was determined. Table 1 provides an overview of the types of modification being commercially produced in each country that responded to the questionnaire. As listed within Table 1, there are a few examples of processes under development. In Belgium, there are plans to develop a new furfurylation plant in a collaboration between Kebony (Norway) and Transfurans Chemicals (Belgium) and Foreco (Netherlands), with initial productions volumes estimated at 20,000 m3.

Table 1: Wood modification voumes in some selected European countries

Country	**Acetylation**	**Thermal modification**	**Furfurylation**	**Silicate/ Silanes**	**Resins**	**Waxes / Oils**	**Mixed anhydride**	**Thermo-hydro modification**
Belgium		++	++ (u.d.)	+ (u.d.)				
Estonia						+		
France		++					+	
Germany		++			n.a.	n.a.		
Hungary								+
Italy		+		+	+			
Macedonia		+						
Netherlands	++	++	+		n.a.			
Norway		+	++					
Poland								+
Romania		+						
Slovakia								
Slovenia		+						
Spain		+						++
Sweden		+		++				
Turkey		++						
Ukraine				n.a.				
UK	++ (u.d.)	+		+	+			

Legend: + Commercial production under 10000 m^3/year, ++ Commercial production over 10,000 m^3/year, n.a. figures not available, u.d. production under development

The use of modified wood continues to increase across Europe. In addition to the three main wood modification processes (acetylation, thermal modification, furfurylation), there has been a recent increase in the number of alternative processes being commercialised. In addition, there has been an expansion of the number of companies producing thermally modified wood, particularly for local use in a given country. The findings of COST FP1407 appear to show similar volumes to those estimated in 2015 (MILITZ, 2015), despite the slow-down within the construction sector. This suggests that modified wood is gaining more favour with architects, specifiers and end-users, which suggests a continued success for modified wood across Europe.

ACKNOWLEDGEMENT

The input of COST Action FP1407 members in collecting national data is gratefully acknowledged as is the funding from the COST Association for the funding of the Action.

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COST Action FP1407 "Understanding wood modification through an integrated scientific and environmental impact approach" - Building the network and impacts of COST Action's networking tools

Andreja Kutnar[1,2]

[1] Univeristy of Primorska, Titov trg 4, 6000 Koper, Slovenia; andreja.kutnar@upr.si

[2] InnoRenew CoE, Livade 6, 6310 Izola, Slovenia; andreja.kutnar@innorenew.eu

Keywords: wood modification, life cycle assessment, environmental impacts, short term scientific missions

ABSTRACT

COST Action FP1407 "Understanding wood modification through an integrated scientific and environmental impact approach" (ModWoodLife) brings together researchers from across Europe and beyond that jointly are addressing the mounting pressure on renewable resources (as a material source, for recreational, ecological, and other uses). By maximising the efficiency of materials derived from them, the wood modification community plays an important role. The efficiency can only be achieved if new methods to improve the functionality, durability, properties, and environmental impacts will be developed. Wood modification addresses these requirements directly, allowing wood to be used in more applications, including increased use of under-utilised species. Wood modification also addresses undesirable characteristics of wood such as fungal resistance, UV-stability, and moisture sensitivity. The COST Action FP1407 has been successful in addressing these needs in the past 3 years. Only sustainable collaboration and joint efforts will deliver the impacts. That objective of the Action FP1407, to characterise the relationship between wood modification processing, product properties, and the associated environmental impacts in order to maximise sustainability and minimize environmental impacts, has great value for the forest sector, for researchers, and society at large. The Action delivered the state of the art of generic Life Cycle Assessments and Environmental Products Declarations of wood products in different Member States. Our other achievements so far include: a systematic comparison of modification processes including their technical characteristics and environmental performance; delivered the state of the art of life cycle analyses of different commercial modification processes; used "cradle to gate" and "cradle to grave" to examine scenarios for the service life and end of life of wood products; recruited industrial stakeholders to become active in the Action; characterized selected modified wood materials and products; reviewed carbon sequestration calculation methodologies; delivered the state of the art on end of life management of wood products; and examined the state of policy positions/actions related to wood/biobased material use.

The Action has delivered three scientific international conferences in Slovenia, Czech Republic, and Austria. In this presentation, the emphasise on the importance of collaboration will be presented through the results of COST Action FP1407. The impacts of FP1407 training schools, short term scientific missions, workshops, and beyond will be presented. Collaboration within FP1407 brings: new possibilities for exploitation and value creation, boosting the innovation potential, international cooperation and mobility of researchers and professionals, transfer of innovation excellence experience, access to infrastructure, as well as breakthrough scientific developments.

Teaming-up for the European Hardwoods Innovation Alliance (EHIA): Take your action!

Andreas Kleinschmit von Lengefeld[1], Uwe Kies[2]

[1] FCBA Institut Technologique, 10 rue Galilée, 77420 Champs-sur-Marne, France, Andreas.Kleinschmit@fcba.fr

[2] Rue du Luxembourg 66, 1000 Brussels, Belgium, InnovaWood, uwe.kies@innovawood.com

Keywords: European hardwoods, innovation strategies, multi-actor approach

ABSTRACT

Hardwoods forests are Europe's largest overlooked renewable resource. Broadleaved tree species account for 43% or 15.0 billion m^3 of the European growing stock in forests. Hardwoods present the natural forest ecosystems in the largest part of Europe. Historically, hardwoods were widely used in construction, furniture, flooring, commodities, paper etc. Today however the forest-based industries in Europe are predominately based on softwood use. The largest share of hardwood today is used inefficiently mainly for energy generation. To valorise better the rich hardwood resource of Europe it is essential to connect the forestry chain with the transforming industries and the final customers. Hardwoods represent the primary opportunity to foster a long-term strategic pathway for sustainable development of the emerging forest-based circular bioeconomy and thus respond to major key societal and environmental global challenges.

The European Hardwoods Innovation Alliance (EHIA) is an initiative under the umbrella of the InnovaWood network in a close collaboration with the European Forest Institute (EFI) and its members. The goal is to enhance collaboration in research, development and innovation to boost the use of the rich variety of this resource. EHIA will expand and coordinate a broad cross-sectorial and transdisciplinary network for the valorisation of knowledge and higher value added use of hardwoods within Europe, based upon excellences in sciences and applied research. The future demand and supply of forest biomass, forest products and ecosystem services, and their implications for sustainable forest management can be enlarged by focussing on the existing and future hardwoods resources in Europe (and worldwide). The role of research and development, especially the impact and use of digitalisation (ICT) and cross-sectoral collaboration across borders can deepen the knowledge about and stimulate ground-breaking innovations in the use of this diverse, pan-European resource.

Hardwood resources are a huge untapped potential that should play a key role in adapting forest ecosystems to climate change and to open new pathways for innovative, knowledge-based products. European citizens will gain from a diverse and rich resource that is the foundation for manifold ecosystem services including the safeguarding of soil productivity, water and air quality, fostering recreation, health and well-being and ensuring vital non-wood forest products. At the same time, broader hardwoods use will allow for the sustainable production of novel, knowledge-based products and services in the fields of construction, interior, textiles, (bio)plastics and various other applications, contributing decisively to the reduction of GHG emission and the mitigation of climate change impacts.

A special focus and efforts is foreseen to integrate and include the outstanding central- and Eastern Europe research capabilities, knowledge and infrastructure, as hardwood forests are part of their key assets.

EHIA partners from all important regions in Europe cooperate with InnovaWood and EFI to deepen the scientific knowledge-base and to feed into the innovation processes for valorisation of the ecosystem services and resources.

It will kick-off in short term the production of high quality COST Action proposals as well as research and innovation projects on regional, national, transnational (Forest Value) and European level.

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Poster Discussion

Wood properties of *Paulownia* Clone in vitro 112

Szabolcs Komán[1], Sándor Fehér[2]

[1] University of Sopron, Institute of Wood Sciences, Hungary, koman.szabolcs@uni-sopron.hu

[2] University of Sopron, Institute of Wood Sciences, Hungary, feher.sandor@uni-sopron.hu

Keywords: Paulownia, density, shrinkage, MOE, MOR

ABSTRACT

Paulownia tree species are one of the fastest growing species in the world, there are 6 (according to other sources 17) species within the family. Due to their rapid growth and value in the timber market, many Paulownia species are cultivated in several temperate zones worldwide (Yadav et al. 2013). Its wide utilization spectrum ranges from industrial applications (furniture and building timber, base material for paper industry, biomass for energy purposes etc.) through apiculture and medical industry (bark, leaf, flower cluster) to decoration function (park tree, base material of exquisite wood-carving). Owing to its machinable timber of decorative texture it is used in Japan as traditional timber, where a high quality log counts as valuable base material. One of the selected variants of Paulownia tree species by hybridization and cloning is „Paulownia Clone in vitro 112". They are mostly used in furniture manufacturing, but they are also used for the production of fiberboard and biomass. With its rapid growth, its tree is characterized by extremely low density. Exact knowledge of the physical-mechanical properties of the wood has not yet been determined, for which this study is important. The values of *Paulownia tomentosa* are also shown in the examined characteristics, which are originated from a previous study (Komán et al. 2017).

Table 1: Values of the measured densities

Paulownia varieties	density (kg/m^3)		
	air-dry (u=12%)	oven-dry	basic
Paulownia Clone in vitro 112	238,20	222,93	208,56
Paulownia tomentosa	300,18	275,46	264,2

Clone density for Paulownia species is typically extremely low. Air-dry density is 20% lower than that of *Paulownia tomentosa* (Tab. 1.), which is already in the upper range, specified for the balsa (Wagenführ 2007).
Low density values are also indicative of bending characteristics (Table 2.). The static bending strength is nearly 2/3 of the *Paulownia tomentosa*. At the modulus of elasticity, however, there is only a 15% decrease. Despite the lower bending characteristics, *Paulownia Clone in vitro 112* values have a higher standard deviation. For MOR it is 28%- more, while for MOE it is 37,4%-more than that of *P. tomentosa*.

Table 2: Values of the MOR and MOE

		Paulownia Clone in vitro 112	*Paulownia tomentosa*
MOR (MPa)	**average**	28,16	41,51
	min	17,06	28,65
	max	37,77	48,65
	st. dev.	5,99	4,68
MOR (MPa)	**average**	3010,67	3492,86
	min	2095,10	2595,13
	max	4387,69	4142,07
	st. dev.	649,34	472,61

Shrinkage of the Paulownia clone, in contrast to the density and strength indicators, shows higher values than *P. tomentosa* (Table 3.), i. e., its shrinkage properties are less favorable.

Table 3: Values of the shrinkage

		Longitudinal (%)	*Radial (%)*	*Tangential (%)*	*Volumetric (%)*
Paulownia Clone in vitro 112	**average**	0,593	3,207	5,076	8,675
	min	0,020	0,783	1,359	5,603
	max	1,529	7,955	7,671	12,413
	st. dev.	0,332	1,423	1,225	1,222
Paulownia tomentosa	**average**	0,689	2,168	3,732	6,281
difference (%)		-15,38	+47,92	+36,01	+38,11

The deviation ranges from 15to 48% in each anatomical direction. *In vitro 112*, except longitudinal shrinkage, has higher values. The volume shrinkage is 38%-higher, than that of the *P.* tomentosa. The difference between the radial and tangential shrinkage is also less favorable in the *in vitro 112* clone, but it has a more favorable value for the T/R ratio. This value is 1,58 in contrast to the *P. tomentosa* 1,72 value.

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Macroscopic properties and density of Pannonia poplar from West Hungarian sites

Domonkos Ete Farkas, Norbert Horváth *

University of Sopron Institute of Wood Science,

*corresponding author: horvath.norbert@uni-sopron.hu

Keywords: Pannonia poplar, *Populus × euramericana* cv. Panonnia, xylem, macroscopic properties, width of annual rings, growth, density, mature wood, juvenile wood, heartwood proportion

ABSTRACT

In the frame of the OTKA K116216 project called "Complex analysis of the physico-mechanical and surface-physical properties of wood with low density" was able to compare selected wood properties of Pannonia poplar from various sites of Hungary. The Pannonia poplar hybrid hybridized by Ferenc Kopeczky is in demand in Forestry due to the favourable cultivation experiences as well as the beneficial morphologic properties, and high tolerance against common poplar infections (Toth et al., 2006). According to Komán and Molnár (2008) it is the one of the poplar hybrids with highest growth. As a raw material has wide range of opportunities for industrial utilization for example in furniture, cellulose, fibreboard, packaging or match production (Tóth, 1996). Németh et al. (2015) call attention to the high deviations of mechanical properties of various poplar hybrids from various sites, therefore they recommend timber grading before application. By research works at the University of Sopron (former name: University of West Hungary) was verified, that the xylem of the first 20-22 annual rings of poplars in opposition to another wood species did not show lower density than the mature wood. It was also established that the width of annual rings of poplars increasing could not cause lower density and lower strength (Komán, 2012). According to research works from Babos and Zsombor (2003) poplar hybrids have intensive growing period at age from 5-6 to 12 years.

Our abstract summarises the preliminary results of the macroscopic properties and density of Pannonia poplar from three different West Hungarian sites of KAEG Zrt. According to macroscopic structure of logs from site 540B the trees start their fast-growing period from their 3rd annual ring, which seemed to last to the 10th. Their annual rings could reach a width of ten millimetres in four years, therefore the average value in case of this site was the highest (7,4 mm) in comparison (Table 1). The fast-growing period of logs from sites A35 and 11G could be observed between the 4th and 10th and 6th -13th annual rings. The average density in normal air conditions (20°C temperature and 65% relative humidity) was the highest in case of the samples from site 11G however, the heartwood proportion related to tree diameter, the width of annual rings and the age of trees showed the lowest values.

Table 1: Macroscopic properties and density of Pannonia poplar from different sites - average values

site code of KAEG Zrt.	35A	11G	540B
diameter of logs [mm]	351,7	257,2	354,8
width of annual rings [mm]	6,1	5,8	7,4
heartwood proportion [%]	71,7	53,6	63,4
age of trees / logs [years]	29	22	24
density $\rho_{norm.\ climate}$ (kg/m^3)	409,6	459,6	420,3

Our preliminary results with emphasis on the macroscopic properties and density show special needs of enlarging the investigation on other Hungarian sites and complex evaluation of the wood properties of Pannonia poplar. Therefore, further investigations are already in progress at the University of Sopron.

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Cultivation of Black Locust Plantations

Dr. László Erdős

H-1121 Budapest, Szanatórium u. 3/b. mosanszky@t-online.hu

Keywords: Growing quality hardwood demand, wood production on arable land, export commodity bases, profitable land use

ABSTRACT

The concept of plantation forests has been driven by the growth in demand of the social and welfare services of forests. Today, the cultivation of conifers, poplars and various certified eucalyptus varieties are spreading across the world through agronomic methods on agricultural land, which is a decisive factor in world wood supply. Domestic climate and soil conditions are favourable for the production of Black Locust; it is also the most common species in Hungary. The growing demand for quality industrial hardwood and energy needs justify the examination of plantation methodologies and the hence produced raw wood more specifically in regards to long term land use in agriculture and rural development.

Using European and overseas experience in the field of tree plantations, the author has initiated an experiment for cultivating Black Locust plantations (IZINGER 1991), mainly funded privately and motivated by agricultural policies. This was accomplished by the gradual stand conversion of a 5-year-old Black Locust plantation.

The Climate and Soil Conditions of the Test Plantation

Mikebuda 40V 3.65 ha. Sand ridge between the Danube and the Tisza, sandy soil with low humus content (0.47%). Precipitation: 400-650 mm, repetitive droughts every 3-4 years, 6.5 AK / ha, according to German soil classification 15-20 Bodenpunkte.

In order to perform the mechanical soil cultivation, every third row of trees was clear cut. According to the development of the plantation, the initial 6000 seedling/ha stock was continuously reduced by thinning every 4 years. In the 10th and 12th year altogether 22 t/ha organic fertilization took place on the V-VI. ranked quality soils (gróf FORGÁCH 1939.). The annual growth was examined in 10 parcels of size 200 m^2 with 160-170 trees inspected every year. As a result of providing more space for growth and the mechanical soil cultivation the wood volume at 9 years was already $17m^3$/ha. This was further enhanced by the organic fertilization to over $20m^3$/ha.

At 24 years, the average tree sizes were: h: 20 m; d (1,3): 24 cm; N: 550 pcs / ha.

Gross increase of 15.6 m^3 / ha pre + end product expected yield was net 303 m^3. The increase in yield is twice as high as the national average of Black Locust in Hungary, and is identical to the II. class wood production table of the Sopp yield chart.

The quality of the timber obtained greatly exceeds the level of traditional stock raising, the proportion of logs, trimmings and rods are well above 55%. Additional experiments should be planned with 3000 seedlings/ha and with a 20-year rotation period. Supplementation of nutrients in the absence of organic fertilizers can be achieved with green manure. These may include compost, sewage sludge, hay etc. or another alternative cheaper organic matter (WESTSIK 1927). With this process, average yield is expected to exceed 20 m3 / ha, which will significantly increase profitability.

The Market Position of Black Locust Wood Products

It is well-known that the Black Locust hardwood has a wide range of applicability and is therefore used for many different purposes. It is one of the most expensive and most highly demanded firewood whilst it is also a support system for vineyards, fruit plantations, water, avalanches, shore protection and recreational products. There is a particularly high demand for sapwood strapped material. They are common all across Europe, and can even be considered a Hungaricum. The furniture and wood industry processes the large and high quality logs with modern processes (drying, tiling, bonding, thermal finishing) and prepare end products such as interior decoration, outdoor wood panels, furniture parts, glued supports etc. The necessary raw wood material required to match the market demand can only be obtained from such wood production plantations. Due to the decline in tropical timber imports, foreign demand for such quality wood material is extremely high (SZALACS 2017).

The Hungarian Black Locust research, with the aid of the beekeepers, has achieved internationally significant results in relation to breeding, timber quality knowledge and technological developments. Despite this, civil organizations have made it difficult for these results to be put into practice. They reason with the fact that Black Locust is not originally native in Europe.

The author compared the Agricultural Research Institute's data on the cost of wheat production and the cost of 4 Black Locust timber products for the period 2013-2015. This showed that the wood product profitability is 220% higher than that of wheat. The timber products also have a comparative advantage and favourable terms of trade. This data highlights the profitability of the production of quality hardwood material when compared to wheat or other grains at marginal production sites. It is therefore vital to publish more information on wood production plantations in order to draw more attention to this important matter.

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The measurement of wood shrinkage and bark thickness on increment cores

Hardwoods in the French Forests

Baptiste Kerfriden[1,2], Lucile Savagner[1,2] , Kevin Dupont-Marin[1,2], Jean-Michel Leban[1, 2]

[1] INRA/BEF 54280 Champenoux, France,

Baptiste.Kerfriden@inra.fr, lucile.savagner@inra.fr, jean-michel.leban@inra.fr,

[2] IGN//Laboratoire de l'Inventaire Forestier, 54000 Nancy, France

Keywords: wood shrinkage, bark thickness, hardwoods, National Forest Inventory

ABSTRACT

Nondestructive field measurement methods are commonly used by foresters since the invention of the Pressler or Swedish increment borer at the end of the 19th century. The first objectives were counting the tree ages and the measurements of ring width in the context of growth and yield modelling. Sixty years later, the pioneer work performed in France (Polge, 1978) opens the perspective of the measurement of several wood properties from increment cores: the wood density, the fiber length, mechanical properties (Bucur, 1983) and the wood shrinkage. Such measurements were and still are time consuming. Here we will give a focus on wood shrinkage and bark thickness measurements, two traits of interest in the context of forest carbon accounting

Shrinkage is one important wood trait (Zhang et al., 2017), often not well correlated with wood density (Dundar, 2013), and needed for the conversion of dry density to basic density, while the bark thickness is of interest for the computing of the standing wood volume by the mean of on bark DBH measurements (Stangle et al., 2017).

In this contribution we present a new method for the high speed measurement of both shrinkage and bark thickness by the processing of optical images of increment cores in the context of the National Forest Inventory. For improving our national forest carbon accounting figures we have implemented a new method for the collection of all the increment cores sampled every year by the NFI technician staff (Leban & al., 2016).

The increments cores are stored in alveolar polycarbonate plates, sent to our lab where an optical scan is done on fresh cores, a second one being performed after drying 24h at 103°. We developed an ImageJ@ plugin that permits the measurement of both wood traits.

We will present the first results obtained for main hardwood species sampled in the French forests and discuss the interest and limits of this new approach

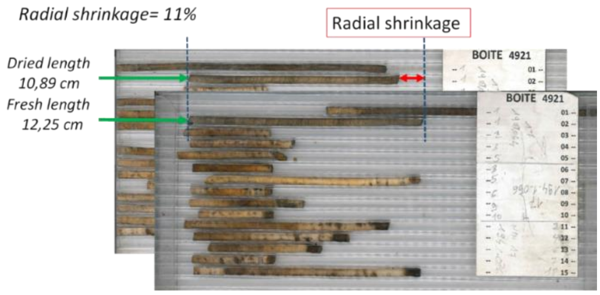

***Figure 1:** one alveolar polycarbonate plate, the first scanned image is made before drying (fresh), the second one after drying (24h at 103°C). The length measurement of the same cores, fresh and dried, allows the calculation of the total radial shrinkage. The same type of measurement is made for bark thickness*

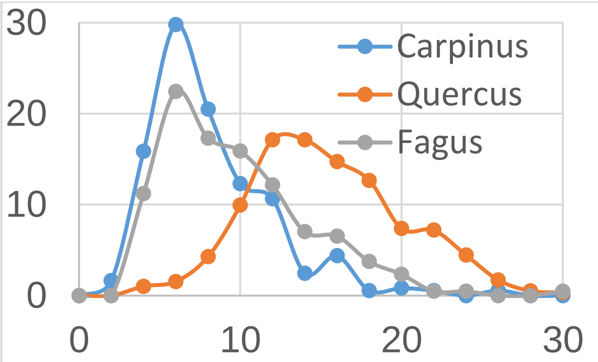

***Figure 2:** horizontal axis is the double bark thickness in mm, vertical axis is the percentage of the total number of measurements: the range of variation is huge and the oak bark thickness is higher than for beech and hornbeam*

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Relationship between density and moisture content of firewood

Sándor Fehér[1], Máté Miklós[2], Dávid Major[2], István Schantl.[1]

[1] University of Sopron, Institute of Wood Sciences, Hungary, feher.sandor@uni-sopron.hu

[2] University of Sopron, Timber Industry Engineer Student, Hungary, miklosmate01@gmail.hu

Keywords: firewood, wood species, density, moisture content

ABSTRACT

The use of firewood, despite the expansion and variety of different energy sources, has not decreased in recent decades. It has even increased. On the one hand, for this contributed the fact, that fossil fuels are depleted, and also, that heating with biomass is exercised at a high level nowadays, although, the price of the firewood is constantly increasing. Today in Hungary, approximately 7-7.5 million cubic meters of firewood is produced. It includes trunk, thick bough wood and thin bough wood, etc. About 50 -51% of this large amount of wood is used for energy production.

Due to these characteristics, the raw material plays a very important role in firewood trade. The economics of burning of firewood, from the point of view of raw material is determined by the following factors: tree species, density and moisture content. All in all, it is favorable, if wood, as high of density as possible, is used for energy gain. Moisture content is also of great interest regarding economic burning. High moisture content causes energy loss, when burning firewood, since a lot of energy is lost, to evaporating unnecessary water.

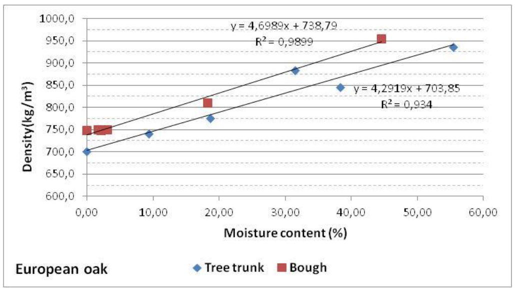
Trade in firewood never belonged to an easy-to-understand trade activity, that is easily transparent and providing satisfaction for both the buyer and the trader. The introduction of EUTR did not completely solve the trade problems of firewood. The aim of the research project is to ensure fair and reliable activity on the part of the trade chain, both on the producer and on the merchant side, and also, that the user should get „quality” goods.

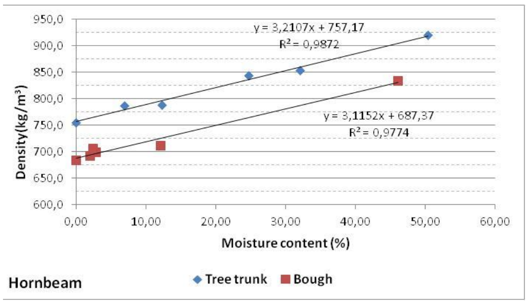
For the examination of relationship between density and moisture content, we connected six forestry companies, in order to establish relationships among the different tree species in the territories of forests in Hungary. The wood species investigated and the forestry holdings, involved in the cooperation are shown in Table 1.

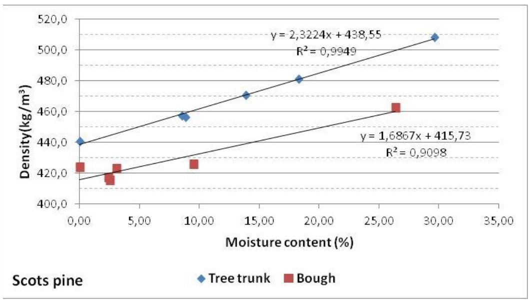
Table 1 The investigated wood species and the forestry holdings

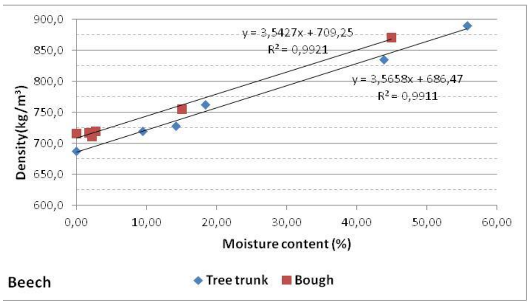
Investigated wood species	Forestry holdings
• European oak (*Quercus petrea, Q. rubra*)	• TÁEG Ltd.
• Turkey oak (*Quercus cerris*)	• Vérteserdő Ltd.
• Beech (*Fagus sylvatica*)	• Zalaerdő Ltd.
• Black locust (*Robinia pseudoacacia*)	• Egererdő Ltd.
• Hornbeam (*Carpinus betulus*)	• Nyírerdő Ltd.
• Scots pine (*Pinus sylvestris*)	• KEFAG Ltd.
• Poplar (*Populus sp.*)	

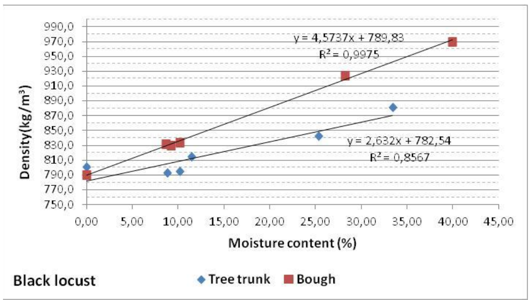
The correlations of density and moisture content were graphically processed, so that the differences between the results of the trunk and the bough tree measurements are presented in prominent way.

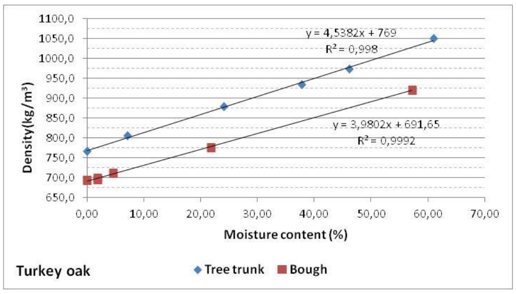


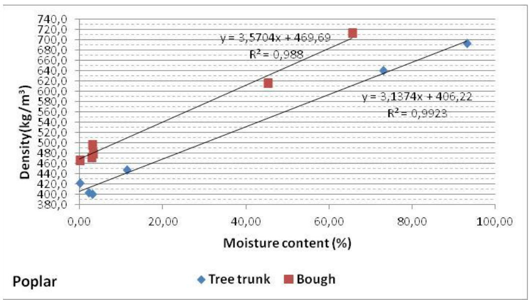












The density of the bough wood is largely distinct from the density of trunk wood. Where the process of dying of the inner part of the wood body has already started, there the density of the bough wood is greater, than that of the trunk wood. The density change of the Black locust is different from the other tree species, related to the bough wood. The increase in moisture content results in a greater density increase. The result of the research work is expected to contribute to the disappearance or suppression in the future of the habitual sales from the „big scales”.

The visual classification and strength values of the oak wood from Borsod area in Hungary

Horváth Dénes[1]

[1] Address of first author, including country, affiliation, and email address

Keywords: oak, saw timber, saw timber classification, non-destructive strength test

ABSTRACT

Demand for good quality oak wood has considerably increased recently. There is a need for higher quality saw timber products made from lower-quality trunks. Earlier, this poorer quality wood was mostly used in the production of slats and parquet flooring. However, tradittional production of the latter was discontinued due to the change in consumers' tastes and the better price-value proportions of the rivalling products. Both reasons had devastating effects on the saw timber industry in Hungary.

The goal of my work for the future is to establish markets for the above mentioned saw timber supplementary products, i.e. slats. In Asian countries large cemented boards (sometimes blocks) are made from similar raw material that we use for slats.

In my publication I examined the quality of saw timber products made at WIS Zrt. (Miskolc) from the aspects of the production of flawless, straight-grained slats which are of different widths and lengths. My aim was to decide how many slats meeting our requirements could be made from the saw timber produced in average circumstances. Applying non-destructive strength tests, I also determined certain features concerning solidity.

I took photos of the data, processed them and gained information for classification and for the quantitative indexes via picture analysis .Next I determined some physical and mechanical features of the sample.

The examined saw timber is basically divided in two groups in the plant: first class and second-third class. I did not examine whether the given groups met the requirements of the standard classification. I only examined if the products could be sold at the price corresponding their own class.

I processed the electronic (visual) data base with the help of a programme, which enabled me to determine the number of slats (even according to slat sizes) in comparison with the assessment of the plant. The size and the quality features of the examined slats mainly equalled those of the raw material of parquet flooring.

I used non-destructive methods to examine the solidity of the slats. I will do some further examinations to find out more about the connections between the data and the classification.

My goal is to get reliable data about the usage or the possible further processing of the slats made from poor quality Hungarian oak timber.

Beech timber for structural purposes – relationship between outer log quality and inner timber quality

C. Fischer[1], F. Brüchert[2], U.H. Sauter[3]

[1]Forest Research Institute Baden-Württemberg (FVA), Germany, email: carolin.fischer@forst.bwl.de

[2]Forest Research Institute Baden-Württemberg (FVA), Germany, email: franka.bruechert@forst.bwl.de

[3]Forest Research Institute Baden-Württemberg (FVA), Germany, email: udo.sauter@forst.bwl.de

Keywords: Beech timber, structural timber, Roundwood quality, structural timber quality.

ABSRACT

In order to respond to climate change there is an on-going silvicultural change in the German forestry. An increase in hardwoods and a decrease in softwoods will have a considerable impact for the German sawmilling industry. Consequently, new markets and products for hardwoods must be developed. Lately, many studies have been undertaken on hardwood timber for structural purposes resulting for example in a general technical approval for beech glulam (DIBt 2014). However, economic restrictions, due to material price and more complicated processing, and lower yield, are still factors that decelerate the implementation of structural timber from hardwoods at the market. Therefore, it is absolutely necessary to provide more information about the raw material, particularly about necessary quality and dimensions of the raw-material to reduce production costs.

This project focuses on the evaluation of beech round wood dimension and quality for a yield- and economic beneficial use of beech timber for structural purposes.

Material and methods

The study includes 41 beech trees from eight different stands in south-western Germany. The eight stands were located in different growth areas and a variation in elevation was given.

The standing trees were quality evaluated using the assessment approach by MAHLER ET AL. (2001).

After harvesting, the trees were cut into logs between 4.0 m and 5.0 m length depending on optimal yield achievement. The logs were graded according to RVR (ANONYMOUS 2015). After sorting, all logs were CT scanned with a Microtec log computer tomography and dynamic modulus of elasticity was determined using Viscan. Finally, the logs will be sawn into boards and the board quality will be assessed.

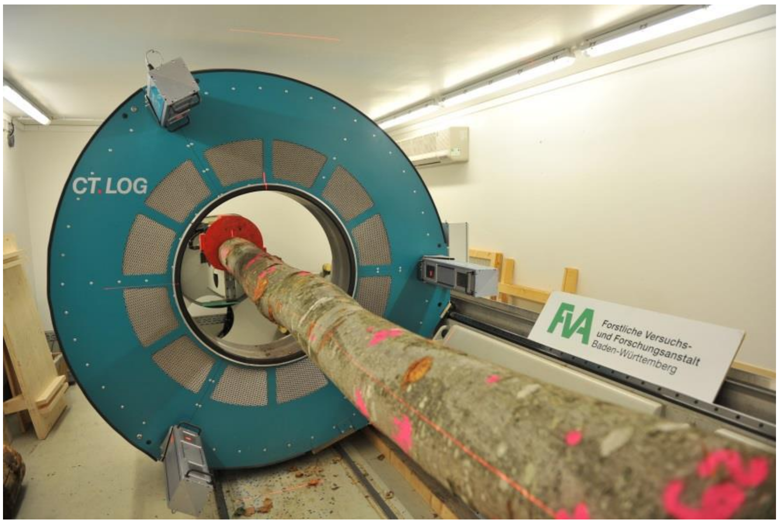


Figure 1: Microtec CT.LOG at the FVA in Freiburg scanning a beech log.

Results and Conlclusion

As described earlier the current project focuses on the development of a new assortment of beech timber for structural purposes. Therefore, the project will investigate in the correlation between standing tree and roundwood quality as well as structural timber quality.

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The possible effect of oak extractives leaching on prolongation of the exterior transparent coating durability

Aleš Zeidler, Miloš Pánek, Eliška Oberhofnerová

Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague 165 00, Czech Republic,

zeidler@fld.czu.cz, panekmilos@fld.czu.cz, Eliska.Oberhofnerova@seznam.cz

Keywords: oak wood, leaching, transparent coatings, accelerated weathering

ABSTRACT

This research deals with the impact of extractives leaching from oak wood, due to weather exposure (sunlight and rain action), on prolongation of service life of the transparent coating system. Samples of oak wood (*Quercus robur*, L.) with initial color coordinates L^*= 65.67 (SD=2.7); b^* = 7.0 (SD=0.5); a^* = 21.2 (SD=1.6) (CIE 1986) were exposed to the exterior conditions in Prague according to EN 927-3 for 20 weeks. The extractives of oak are rapidly photodegraded (ZAHRI ET AL 2007) and washed out due to rain, which causes color change (Figure 1).

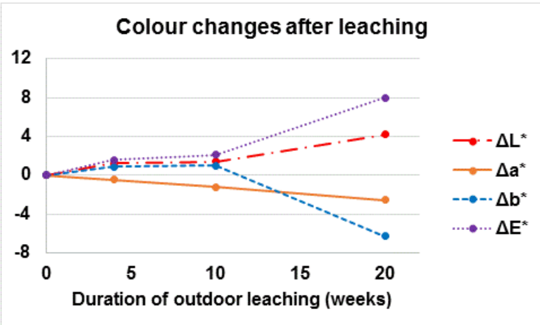

Figure 1: Colour changes of native oak wood during 20 weeks of weathering

To the weathered oak we applied coating system composed of brown mordants (to achieve again natural colour of oak) and 2 layers of OSMO UV420 (OSMO HOLZ und COLOR, Germany) coating. As the top layer we applied hydrophobic coating Aquastop (Böhme, Switzerland) (10 weeks of leaching CHL1; 20 weeks of leaching CHL2). Subsequently, the following coatings systems were used for non-weathered oak wood: 2 layers of OSMO UV420 (C) coating together with hydrophobic layer Aquastop (CH). We also tested an untreated oak wood (REF).
Samples were exposed during 6 weeks of artificial accelerated weathering in the UV chamber in accordance with EN 927-6 in combination with frost cycles. In the course of the artificial weathering, we were measuring the color changes by spectrophotometer, wetting contact angle and even visual changes were monitored. The method of the artificial accelerated weathering and its measurement is described in details in the work of PÁNEK ET AL. (2017).
In general, the effect of extractives leaching on stabilization of the coating system for oak was not confirm (see CHL1 and CHL2 in Figure 2), because the same coating system without leaching (CH) had a better color stability and was also characterized by a slightly increased overall lifetime (Figure 3) . This may be caused by non-homogeneous surface of oak wood (WAGENFÜHR 2002) and due to microcracks (RACZKOWSKI 1980), which developed during the initial weathering and negatively influenced the lifetime of the coating system.

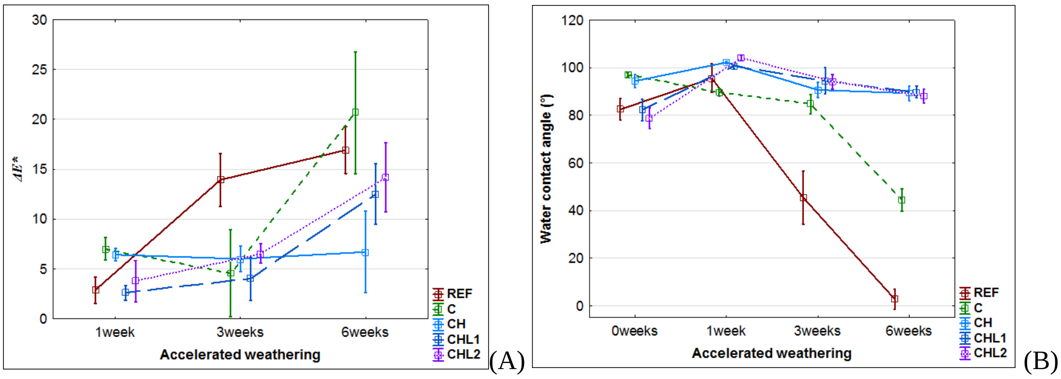

***Figure 2:** Colour (A) and surface wetting (B) changes of coated oak wood during accelerated weathering*

***Figure 3:** Visual changes of oak wood with different coatings during 6 weeks of accelerated weathering*

The results showed a significantly positive effect of using the top hydrophobic layer to increase the durability and color stability of the tested coating systems (see C versus CH in Figures 2 and 3). The top hydrophobic layers can extend the service life of the coating systems for exterior conditions (GHOSCH ET AL 2009). The work confirmed this statement for oak wood, which is a problematic timber from the view of surface treatment with transparent coating systems.

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Culture growth of *Phellinus contiguus* under laboratory conditions

István Eső[1], Norbert Horváth[2]

[1] University of Sopron – SKF - IWS, PhD student, eso.istvan@phd.uni-sopron.hu

[2] University of Sopron – SKF - IWS, associate professor, horvath.norbert@uni-sopron.hu

Keywords: *Phellinus contiguus*, wood protection, culture growth, white rot

ABSTRACT

The white rot fungi *Phellinus contiguus* is commonly found in the forests of Europe, therefore there are plenty of recordings of its distribution and identification. The main focus of literature is better identification of the specie by traditional light-microscopy (Schmidt et al., 2006) and new DNA analysis (Fischer et al., 2001) methods. In contrast with its rich recordings in the wild, there are very few information on its optimum growth conditions (Butler et al., 1988), wood decaying method and its appearances in built environment.

While on living trees the fungi usually destroy its host short after growing multiple small fruiting bodies, indoors since perennial white rot fungi, *Phellinus contiguus* is capable of growing up to 1,5 m long and 30 cm wide fruiting bodies over the years, causing large amounts of damages in the wooden structure. Interestingly, while in forest *Phellinus contiguus* is found only on deciduous trees, it has been encountered on built in *Picea abies* multiple times in Hungary, which is the main wooden construction material in the country. Fruiting bodies has been found on roof deckings, roof structure elements, window sill and window framework.

Although Butler and associates carried out multiple experiments about growing factors of this polypore, their main goal was to characterise the fruiting inducing factors of *Phellinus contiguus,* not to produce viable mycelium. These studies were a good starting point to determine the optimal environmental factors in which the fungi is capable of producing mycelium usable for determining the wood decaying capacity of the fungi. After experiments on different wood powders (*Picea abies*, *Pinus sylvestris*, *Larix decidua*, *Quercus robur*, *Fagus sylvatica* and *Robinia pseudoacacia* sapwood and heartwood), in different humidity and temperature it was determined *Phellinus contiguus* grows fastest in 30°C temperature but perishes in 35°C and grows more and richer mycelium in high humidity: 90 %rH (Fig. 1). In lower temperatures the fungi produce a slower growing but thick mycelium layer that can be used for wood decaying capability testing.

Since the standard wood decay test takes sixteen weeks, it gives the opportunity to observe the wood decaying process by taking samples of the inoculated wood every week. Observing primarily the decay of lignin gives the opportunity to evaluate the results of different testing methods. Chemical analysis determines the amount of lignin and holocelluloses which can be compared with the result of stained microscopy slides, SEM (Schwarze, 2007) and FTIR spectroscopy (Bari et a., 2015). This way the process of wood decay and fungi development can be observed in chronological order and the course of macroscopical, microscopical and chemical changes can be determined.

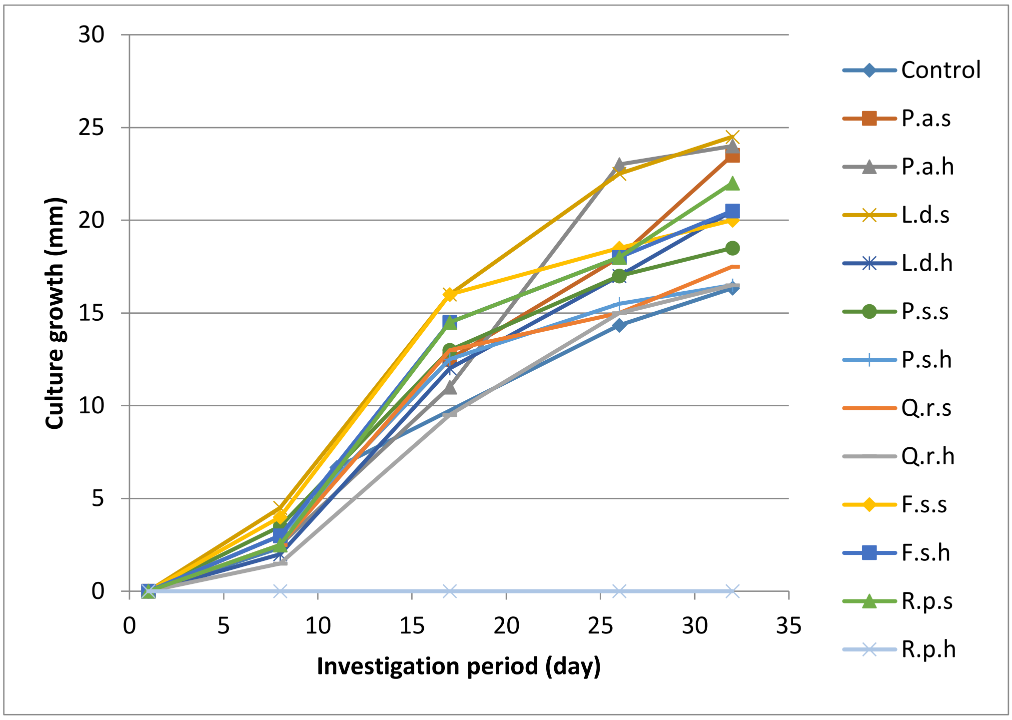

Figure 1: Culture growth on sap- and heartwood powder, 20°C 90% rH

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Performance amelioration of imported timber with environ-safe preservaticve ziboc

Sadhna Tripathi[1] , Akhato Sumi[2] and Sauradipta Ganguly[3]

[1,2,3] Wood Preservation Discipline,
Forest Products Division,
Forest Research Institute, Dehradun
India

Keywords: Copper-chrome-arsenate , Meranti , treatability, ZiBOC,

ABSTRACT

The economic liberalization polices initiated in 1991 have led India the path of increased economic growth and greater economic stability. Earlier there was a plenty of supply of durable timber but due to decline in the availability, people have switched over to plantation species. Till last decade plantations grown species are major source of raw material supply to the domestic wood based industries but due to rapid industrialization and demand, the availability of raw material became a problem. Therefore, restrictions on harvesting from indigenous forests coupled with limited forest resources had oriented the approach of industries to rely on imported timbers to fill up the gap between demand and supply. Timbers being lignocellulosics are susceptible to biological decay in varied environments especially in tropical region. Hence, it is essential to study the natural durability of imported woods in Indian climatic condition as tropical countries cannot be compared with temperate countries. Therefore, the present project was undertaken to study the natural durability/durability improvement of imported woods in Indian climatic condition. In the present project treatability evaluation of Malaysian red, yellow and white meranti of *shorea* group by using commercial copper-chrome-arsenate CCA and ZiBOC- new preservative system was studied and white meranti exhibited treatability class 'a' while red and yellow meranti exhibiting class 'c'. Douglas fir is difficult to treat and categorized in'd' class hence to impart durability a new method of treatment was developed. Technique is ready for transfer to industry. Resistance against termites in mound revealed complete protection after preservative treatment. Average retention of preservative is: D.fir > white mearnti >Red meranti > yellow meranti. Stake test at three locations exibited that all test species without preservative treatment (control) are non durable. While after treatment the avearage data of damage revealed that both the preservatives had protected all test species satisfactorily. Till date conventional preservatives are in practice, in the present study a new environ-safe preservative ZiBOC developed in Forest Research Institute, Dehradun India suggests that ZiBOC is suitable for out side inground application also and the efficacy is at par with CCA.

Impregnation of *Tilia tomentosa* with paraffin

Szabolcs Komán[1], József Ábrahám[2], Dávid Varga[3],

Udo Beck[4], Bence Katona[5]

[1] University of Sopron, Institute of Wood Sciences, Hungary, koman.szabolcs@uni-sopron.hu

[2] University of Sopron, Institute of Wood Sciences, Hungary, abraham.jozsef@uni-sopron.hu

[3] University of Sopron, A.W. Faber-Castell Vertrieb GmbH, Germany, david.varga@faber-castell.de

[4] University of Sopron, A.W. Faber-Castell Vertrieb GmbH, Germany, udo.beck@faber-castell.de

[5] University of Sopron, Hungary, katonabgy15@student.uni-sopron.hu

Keywords: *Tilia tomentosa*, density, paraffin, impregnation

ABSTRACT

Nearly 40 species of linden genus are known, from which *Tilia cordata*, *Tilia platyphyllos* and *Tilia tomentosa* are indigenous in Hungary. In the largest quantity (12.300 ha) there is silver lime with an area ration exceeding the sum of the other two pieces. The lime trees have a smooth, fine structure, so mechanical processing and surface treatment does not cause any problem. Its use is multifaceted with the natural materials, needed for preservation, for example impregnation with paraffin. Paraffin is often used to preserve historical findings and other areas where the product's resistance to water is to be improved. Treatment of silver lime with paraffin is also used in the case of pencil production where it is important to saturate the raw material in full cross-section. To achieve this, the exact knowledge of technology times and other influencing factors is indispensable, regarding which this research provides help.

The experimental samples were 4x8x20 (radial×tangential ×longitudinal) cm in size and had 7-7,5% moisture content (dry basis). The aqueous paraffin emulsion was painted, to visualize the penetration depth. Treatments were performed with 3 different methods, but with the same vacuum and pressure values. Changed parameters were in the duration of vacuum and pressure used. Prior to treatments, the density of the test pieces was determined by mass and volume measurement.

The test results show, that regardless of the treatment methods employed, the density has a clear influence on the amount of emulsion uptake. The correlation values are very high for all three treatments (Table 1.).

Table 1: Correlation coefficients between density and emulsion uptake

treatment method	correlation coefficient
1h vacuum, 2 h pressure	0,9241
1h vacuum, 4 h pressure	0,9494
2x (0,5h vacuum, 1 h pressure)	0,9713

Density of examined samples were between 0,4-0,59 g/cm^3, which is the same as in the various literature (Korkut 2011, Wagenführ 2007). The amount of material collected, related to the pre-treatment weight is shown in Figure 1. The lower the initial density, the higher the emulsion uptake. The results show, hat the material, the density of which is less than 0,4 g/cm^3 can uptake nearly two times of its original weight, while in the case of materials, the density of which is

above 0,6 g/cm^3 can uptake the same amount as their original weight. The applied treatment periods were of no relevance in this respect.

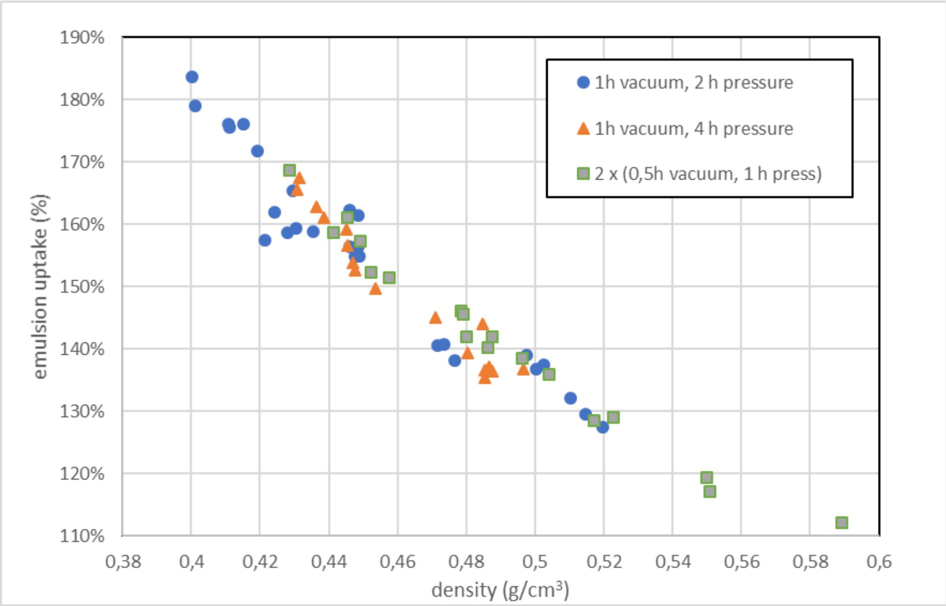

Figure 1: The relationship between the density and emulsion uptake.

ACKNOWLEDGMENTS

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The impact of heat treatment on the hardness of European birch wood

Vlastimil Borůvka[1], Aleš Zeidler[2], Tomáš Holeček[3], Roman Dudík[4]

[1] Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague 165 00, Czech Republic, boruvkav@fld.czu.cz

[2] Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague 165 00, Czech Republic, zeidler@fld.czu.cz

[3] Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague 165 00, Czech Republic, holecekt@fld.czu.cz

[3] Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague 165 00, Czech Republic, dudik@fld.czu.cz

Keywords: birch wood, heat treatment, hardness, horizontal position

ABSTRACT

The research is focused on the influence of heat treatment on the hardness of the wood of European birch (*Betula pendula* Roth.), which was determined at two temperature stages of wood treatment, namely at 170 and 190 °C, in accordance with the patented Finnish production technology (VIITANIEMI ET AL. 1995). The lab high-temperature chamber Atype KHT (Katres Ltd., Jihlava, Czech Republic) was employed to modify both sets of the testing samples. The testing samples were conditioned after the treatment to reach the equilibrium moisture content (approx. 12% for untreated wood). We used the Climacell 707 conditioning chamber (BMT Medical Technology Ltd., Brno, Czech Republic) at 20 ± 2 °C and a relative humidity of 65 ± 5%.
The course of hardness in the horizontal direction, i.e. along the trunk radius, in the basal part of the tree was evaluated. The testing material, representing 8 trees of European birch, comes from the Školní Lesní Podnik (Forest Establishment) of the CULS in Kostelec nad Černými Lesy (Czech Republic). Discs, both reference and modified, were exposed to the ball pushing with a force of 500 N using DuraVision-30 (Struers GmbH, Willich, Germany) equipment at the distances following the radius from the pith to the bark (see Fig. 1). The obtained results are values of Brinell hardness in the transverse plane in MPa in accordance with the standard ČSN EN 1534.

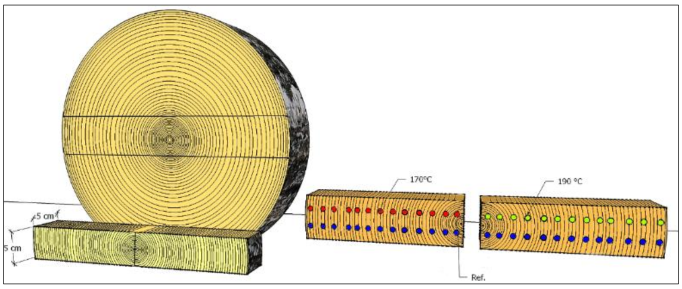

Figure 1: Scheme of test samples and way of experimental measurement

The measurement was performed for the first time before the treatment and then after the heat treatment (see Fig. 1). A statistically significant effect of the heat treatment was observed (see Fig. 2 left), where at 170 °C the average hardness values increased by 6.4 % and at 190 °C by 5.6 % in contrast to the reference samples, i.e. without modification. This trend is in the line with literature, for example PONCSAK ET AL. 2006, BORŮVKA ET AL. 2018, ITA 2003. The course of hardness along the radius of the trunk (see Fig. 2 right) has a logically increasing trend as well as the increasing variability in the peripheral part near the bark, according to the following literature ZOBEL AND BUIJTENEN 1989, ZOBEL AND SPRAGUE 1998.

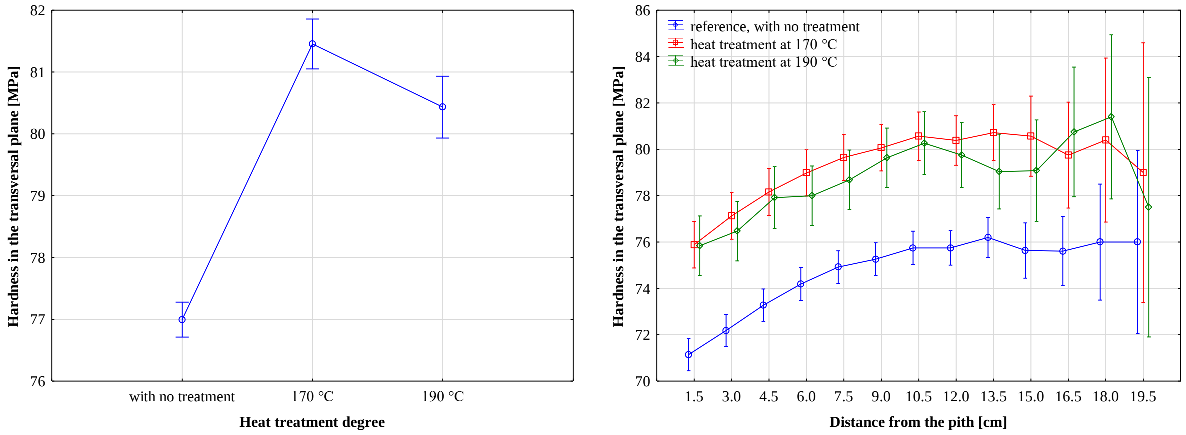

***Figure 2:** Graphic visualization of the effect of heat treatment temperature on hardness (left) and the hardness profile in the horizontal direction along the radius of the tree (right)*

The results demonstrated the positive effect of the selected heat treatment stages on the hardness of the birch wood. We didn't experience any negative decrease compared to the untreated state under the given test conditions. This fact is related to the lower moisture content of the heat-treated wood compared to the reference wood. Moreover, the treatment temperatures are not so high yet to cause significant changes in the chemical structure. In this work, this was proved to be true throughout the whole trunk radius.

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Colour modification of poplar wood by steaming

Endre Antal Banadics

Institute of Physics and Electrotechnics, University of Sopron, Bajcsy-Zs. str. 4. Sopron, Hungary H-9400. banadics.endre.antal@phd.uni-sopron.hu

Keywords: poplar, black locust, steaming, colour modification

ABSTRACT

During steaming, structure and components of natural wood material are affected by heat followed by physical and chemical transformation of wood components such as hemicelluloses and extractives (Tolvaj et al. 2010, Csanady et al. 2015, Nemeth et al. 2016, Xin et al. 2017). Poplar and black locust - as initiator - specimens were steamed together at 110°C temperature to observe the joint effect of steam and excipient on the poplar wood colour. The aim was to find which parameters have an influence on the colour of poplar.

Materials and methods

Dried poplar timber (*Populus x euramericana cv. pannonia*) and black locust (*Robinia pseudoacacia*) was steamed together for 20 days. Samples with a dimension of 30 × 25 × 160 mm (W × H × L) were prepared using both sapwood and heartwood separately. The initial moister content of the samples was 8-12%. The volume ratio of poplar and black locust was 50%. The steaming was carried out in a special pot, which was able to keep inner pressure. The steaming temperature was 110°C. The dry steamed samples were cut longitudinally in the middle and the colour measurements were carried out on the freshly formed surface. The changes were followed by colour measurement according to the CIELab system. The colour coordinates were measured by a colorimeter KONICA-MINOLTA 2000d. The light source was D65 illuminant and 10° standard observer with a test-window diameter of 8 mm were applied.

Results and discussion

Compared to visual observation, objective colour measurement gives more detailed and accurate information regarding the colour alteration. Fig. 1 shows lightness change of poplar as function of treatment time. The value of lightness was reduced significantly in all cases. The initial colour of heartwood (HW) was darker (3 units) than that of sapwood (SW). The lightness of heartwood changed almost equally during the steaming period in both cases, with or without excipient. The colour of sapwood changed during the first five days similar way to that of the heartwood. Then the curves moved away from each other over time. The colour of singly steamed poplar sapwood (C-SW: control sapwood) got closer to that of the heartwood, while the light reduction of poplar sapwood steamed along with black locust slowed down. Therefore, the greatest (24 units) and the lowest (18 units) lightness decrease was observed by sapwood during 20-day steaming at 110°C.

The initial redness of poplar specimens was low, 2.36 and 2.58 for heartwood and sapwood, respectively. This is because the extractive content of poplar is low. It means that extractives were not the main generators of redness increase. The redness value increased continuously for all specimens by elapsed steaming time. The continuous redness increase demonstrates clearly that the degradation products of hemicelluloses play dominant role in redness change of poplar during steaming. The a* values of sapwood and heartwood were close to each other during steaming at 110°C. The redness change was not influenced by the excipient. The highest redness

value achieved by the singly steamed poplar sapwood was 11.55 units, which can be generated at 110°C by 20 days steaming. This is 4.5 times higher than the initial redness value.
Fig. 2 represents the yellowness change caused by steaming at 110°C. The treatment generated significant yellowness increase for sapwood and slight increase for heartwood if steamed without excipient. It was observed, that the presence of black locust has a considerable impact on the yellowness change of poplar heartwood. During the first 2 days, the b* of heartwood rose to the level of sapwood and this difference was maintained for the remaining time. The highest yellowness value, which can be generated at 110°C by 20-day steaming, is 33.54 units. This is 1.9 times higher than the initial yellowness value.

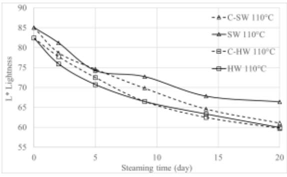

Figure 1 Lightness change of poplar caused by steaming as a function of treatment time (SW: sapwood, HW: heartwood, C: control)

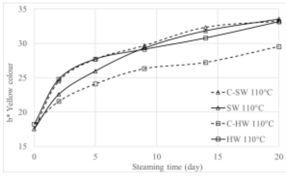

Figure 2 Yellow colour change of poplar caused by steaming as a function of treatment time (SW: sapwood, HW: heartwood, C: contro)l

Conclusions

Poplar was steamed at 110°C together with black locust - as excipients - in order to improve the colour of poplar. The colour change of both sapwood and heartwood was monitored in CIELab system. Steaming increased both redness and yellowness values and reduced the lightness. Steaming generated much greater redness increase than yellowness increase. Steaming of poplar can multiply the initial redness value by 4.5 and the yellowness value by 1.9. Based on our results, it can be stated that the excipient does not have a significant impact on colour coordinate a*, however, it has an influence on L* (reduce the change) and b* (increase the change) colour coordinates.

ACKNOWLEDGEMENT

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Thermal properties of thermo-treated native black poplar wood

Luigi Todaro[1], Giacomo Goli[2], Paola Cetera[1], Pietro Stefanizzi[3], Stefania Liuzzi[3], Antonio M. Pantaleo[4]

[1] S.A.F.E, University of Basilicata, V.le Ateneo Lucano, 10 - 85100 Potenza, Italy. luigi.todaro@unibas.it; paola.cetera@unibas.it

[2] GESAAF, University of Florence, Via S. Bonaventura, 13 - 50145, Firenze, Italy, giacomo.goli@unifi.it

[3] DICATECh Politecnico di Bari, Via E. Orabona, 4 - 70125 Bari. (pietro.stefanizzi@poliba.it; stefania.liuzzi@poliba.it)

[4] DiSAAT, University of Bari, Via Amendola, 165/A - 70126 Bari, Italy. (antonio.pantaleo@uniba.it)

Keywords: Thermo-treatment; native poplar; insulation; conductivity, diffusivity

ABSTRACT

As is generally known wood undergoes changes as a consequence of thermal modification. Extensive research have been published on the field of thermal modification but thermal properties of thermally modified underutilized wood species such as native poplar wood (*Populous spp*) has not been deeply reported. Native poplar such as black poplar (*Populus nigra L*), widely distributed across Europe, Asia and northern Africa is considered as an important species of floodplain forests (De Rigo et al 2011) and is one of the cheaper hardwoods. Poplar wood is rarely used in the production of fine furniture, but extensively used for pulp and panel productions that result in an important economic impact worldwide. In order to develop models for predictions in different applications such as facade or fire resistance, reliable data of thermal behaviour of thermally modified wood at high temperatures are needed (Kol and Sefil 2011).

In this work the thermal behaviour of native black poplar after thermal modification according to (Todaro et al 2017) at different temperatures (180 °C, 200°C and 220 °C) was analysed and compared to reference samples (Fig. 1).

Measurements of thermal conductivity and thermal diffusivity in radial direction of poplar wood boards have been performed with ISO-MET 2104 at room temperature. The evaluation was based on analysis of the temperature response of the analysed material to heat flow impulses (Bekhta and Dobrowolsk 2006). Porosity determination was carried out using the automatic pycnometers Ultrapyc 1200e (Co. Quantachrome, USA).

The results (Table 1) indicate that the thermal conductivity of modified wood samples stay unchanged at 180°C but is significantly changed after a modification occurred at 200 or 220°C. Regarding the porosity, only in the samples treated at 220 °C showed a significant difference with the control. This evidence could be caused by the large degradation of wood structure after modification at high temperature. Mass loss increased and both density and equilibrium moisture content dropped down significantly after modification. Preliminary results showed that for selected purposes, where high insulation is needed such as saunas, windows, and for façades elements the use of this material might be a better option than untreated wood.

Table 1: Thermal propertie, porosity, density, moisture content and mass loss of poplar wood treated at different temperatures. Results are for means, (standard deviation), and letter ranking per Duncan's multiple range test for significance level of 0.0. Differences among mean values with same letter are not significant.

	N	T.C. (W/m K)		T.D. (m^2/s)		Porosity (%)		Mass Loss		Density (kg/m^3)		U (%)
CTRL	18	0.124 (0.004)	a	0.172 (0.003)	a	61.3 (1.53)	a	-		441.3	a	9.9
180 °C	18	0.118 (0.004)	ab	0.173 (0.007)	a	59.0 (2.0)	a	4.40 (0.20)	a	406.8	b	7.3
200 °C	18	0.111 (0.004)	b	0.188 (0.002)	b	59.0 (1.73)	a	7.88 (0.77)	b	407.6	b	5.2
220 °C	18	0.100 (0.004)	c	0.189 (0.004)	b	53.3 (0.58)	b	9.67 (0.57)	c	401.5	c	5.0

T.C. Thermal conductivity, T.D. Thermal diffusivity; N number of samples

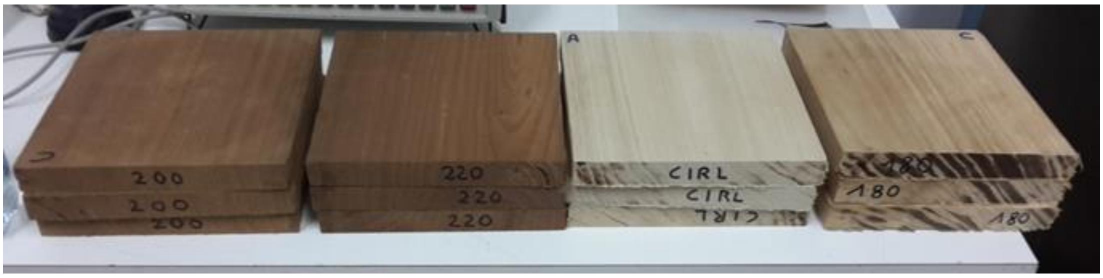

Figure 1: Samples preparation

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Sand abrasion testing of acetylated hornbeam (*Carpinus betulus* L.)

Fanni Fodor[1], Róbert Németh[2]

[1] Institute of Wood Science, Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts, University of Sopron, Bajcsy-Zs. u. 4. Sopron 9400, Hungary, fodor.fanni@phd.uni-sopron.hu

[2] Institute of Wood Science, Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts, University of Sopron, Bajcsy-Zs. u. 4. Sopron 9400, Hungary, nemeth.robert@uni-sopron.hu

Keywords: sand, abrasion, wear resistance, acetylation, wood modification, hornbeam

ABSTRACT

The abrasion resistance of wood can be expressed as the resistance of the surface layers of wood to external abrasive forces. The service life of wood floorings can be predicted by abrasion resistance tests where the real conditions of the wooden product's application area is simulated. Unlike hardness, this property is influenced also by surface properties and the presence of interlocked grain. It is related to hardness and density, but neither the hardness value nor the density of wood sufficiently indicates the degree of abrasive-wear resistance (NCUBE 2008). There are many methods to determine the wear resistance of wood. The most widely spread are the sanding processes which imitate walking (Taber). Abrasive tests can be done with hard metal tools as well. In this paper, sandblasting process will be used where strong sandblast wears the surface of wood. It is difficult to compare these different abrasion methods. The results are usually determined as weight loss, volume loss and depth of wear (thickness loss), which is then compared to the results of natural beech.

Wood modification processes usually decrease the wear resistance of wood because of the degradation caused by increased treatment temperature and acidic medium. ANDRÁSI (2015) found that compared to untreated beech, the mass loss after sand abrasion was bigger by 0.13 g and 0.32 g in case of beech heat-treated at 180°and 200°, respectively. WELZBACHER et al. (2009) also reported slightly higher mass loss (using Shaker test) in case of thermally modified beech. AYTIN et al. (2015) compared the abrasive resistance of untreated and heat treated wild cherry wood, and found that after heat treatment, the wear was higher in case of tangential samples and lower for radial samples. Also, the wear of radial surfaces was significantly lower than tangential surfaces. According to COELHO et al. (2017) the rate of Taber abrasion of thermo-mechanically treated pinewood was slightly lower than untreated pinewood. The best results were obtained in case of higher temperature (190°C) and post-treatment.

Hornbeam is one of the most wear-resistant wood species. It has similar diffuse-porous structure and density (700-800 kg/m^3) like beech wood. Its density and hardness increased by 8% and 49-68% after acetylation, respectively (FODOR et al. 2017). In this study, the aim was to compare the abrasive resistance of untreated and acetylated hornbeam, using sandblaster.

For the tests, hornbeam boards were obtained from the southwest part of Hungary. The air-dry density varied between 750-790 kg/m^3. Half of the hornbeam boards were acetylated at Accsys Technologies (Netherlands) under industrial conditions. The average WPG was 15%. The samples were 5 mm thick and the abrasion was done on tangential surface.

The test was done according to ANDRÁSI (2015) in a closed cabin designed for this purpose. For abrasion, 100 grams of Güde blast furnace slag (0.25-0.5 mm particle size) was used which was blasted with Güde 40046 sandblaster gun at 5 bars on each sample.

In Figure 1, the results of the sand abrasion test were evaluated as the function of density, and they were compared to the results of ANDRÁSI (2015) who tested the wear-resistance of beech and heat-treated beech. In spite of the increased density and hardness, the wear-resistance of

acetylated hornbeam was weaker than natural hornbeam, but these differences are considerably low: the mass loss increased from 0.007 g/100g to 0.025 g/100g and the thickness changed from 0.07 mm to 0.12 mm. Although acetylated hornbeam showed lower resistance to abrasion, it is still among the most wear-resistant wood materials. Only slight surface wear and color difference can be observed after the test. Hornbeam and acetylated hornbeam had smaller wear compared to untreated and heat-treated beech, which had a mass loss of 0.17-0.20 g/100g and 0.30-0.52 g/100g, respectively. According to these results, acetylated hornbeam could be used as raw material for parquet, flooring, terrace, stair cases, decking, and other types of walking surfaces. Because of its high durability, it can be used outdoors as well (FODOR 2017).

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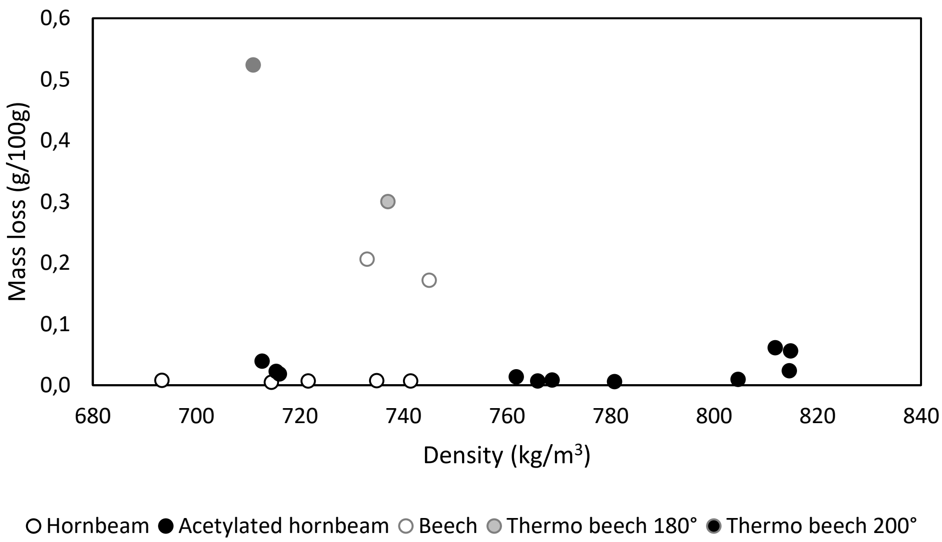

Figure 1: Mass loss of untreated and modified hornbeam compared to beech (ANDRÁSI 2015)

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Combined Longitudinal and Transversal Compression of Beech Wood

Mátyás Báder[1], Radim Rousek[2]

[1] Institute of Wood Science, University of West Hungary, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Sopron, Hungary; E-mail: bader.matyas@uni-sopron.hu

[2] Department of Wood Science, Faculty of Forestry and Wood Technology, Mendel University in Brno, Czech Republic; E-mail: radim.rousek@mendelu.cz

Keywords: densification, compression, wood bending, pleating, shaping, MoR, MoE

ABSTRACT

Longitudinal wood compression or pleating results in bendable wood (BÁDER AND NÉMETH 2017). With longitudinal wood compression, the required bending force and the modulus of elasticity decrease dramatically and provide great bendability to the wood.

The transversal compression of wood improves mainly its strength and hardness (NAVI AND SANDBERG 2012). Plasticized wood is put in a press and compressed in the transversal direction with a certain pressure and subsequently dried in this state. This results in a smaller thickness and higher density. If the press plates are shaped, the specimen will also have the same shape after the process, so the bending of wood is also possible with this process until the limited tension deformation along fibres allows the shaping of the specimen.

Combination of these two methods could allow simple production of more curved wooden shapes with much higher strength compared to conventional bending methods. The aim of this research is to compare mechanical properties of shaped wood prepared by these three methods: longitudinally and transversally compressed (LTC), transversally compressed only (TC) and shaped specimens by the mould without compression (SWC).

The raw material of the experiment was Beech (*Fagus sylvatica* L.). The longitudinally compressed wood was prepared according to BÁDER AND NÉMETH (2017). High quality fresh wood (knot and defect-free, precisely sized, free from cracks and tortuosity, minimal fibre slope, cut from a straight grown tree) was cut into specimens with dimensions 20×20×200 mm^3 ($R\times T\times L$), determined by the laboratory scale compressing machine. All the specimens were plasticized in saturated steam at temperature of 100°C and subsequently compressed by 20% compared to their original lengths. After compression, the treated specimens were relaxed (held compressed for a while in the press) for 1 minute.

Wet longitudinally compressed wood and wet untreated wood were both cut to dimensions 20×13×157 mm^3 ($R\times T\times L$) for LTC and TC specimens. In the case of specimens for bending (SWC) the thickness was 7.8 mm. Plasticization by microwaves reduced the moisture content to 50-65%. Plasticized specimens were subsequently compressed in the transversal direction in aluminium moulds to a shape with an inner radius of 180 mm (Fig. 1a). The pressure applied was 10.0 MPa and 0.6 MPa for compression and shaping without compression respectively. The specimens were fixed in the moulds and were packed in aluminium foil to avoid too fast drying. The packs were dried at temperature of 103°C for a day.

The mechanical properties of the LTC, TC and SWC specimens were compared. Each group contained 12 specimens. Before the bending tests, the specimens were conditioned at a temperature of 20 °C and 65% of relative humidity until a constant weight was reached. The final average cross section of all the specimens was 20×6.8 mm^2 ($R\times T$). The position of annual rings was in vertical direction. The 3 point bending tests (Fig. 1b) were carried out on an Instron 4208 (Instron Corporation, USA) universal material testing machine, where the support span

was set to 130 mm. The loading rate was 16 mm/min according to Hungarian standard MSZ 6786-5 (2004). Tests were stopped upon failure, when the load dropped with no recovery.

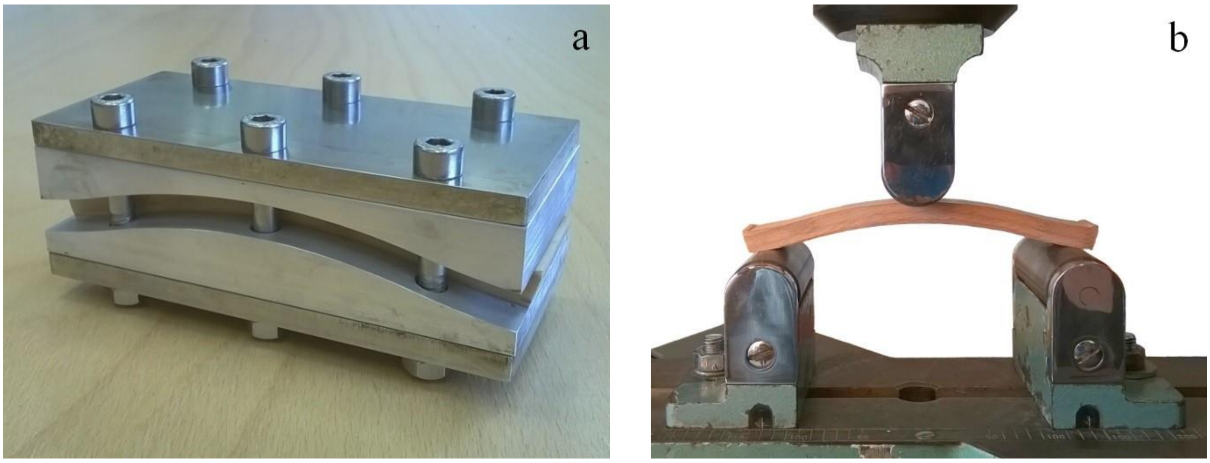

Figure 1: Specimens compressed in a mould (a) and specimen in testing device before bending strength test (b)

The measurements and data evaluation are in progress at the time of the abstract submission. Final results will be presented at the conference. Preliminary results showed that both LTC and TC specimens significantly increased strength to similar values due to densification compared to values for untreated beech wood. Modulus of elasticity was increased too in both cases. However, LTC method resulted in lower values, but the bendability of the longitudinally compressed wood was better.

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Complex assessment of the antioxidant capacity and polyphenol content of wood bark

Esztella Tálos-Nebehaj, Levente Albert, Eszter Visi-Rajczi, Tamás Hofmann

University of Sopron, Institute of Chemistry, H-9400 Sopron, 4 Bajcsy-Zsilinszky str.

email: nebehaj.esztella@gmail.com

Keywords: wood bark, antioxidant capacity, combined multiassay approach (CMA)

ABSTRACT

The investigation of antioxidant properties and polyphenol content of fruits, vegetables and of other plant tissues have already been the subject of numerous studies (e.g. Shui and Leong, 2004; Chan et al., 2011), yet the by-products of forest trees which are barely utilizable (e.g. bark, knots, leaves, cones, root) can also contain antioxidant polyphenols in high concentrations (Lesjak et al., 2011; Sathya and Siddhuraju, 2012), making these by-products possible raw materials for antioxidant extraction and utilization.
The present research focuses on the assessment of the antioxidant capacity and polyphenol content of the bark of 11 selected wood species by the combined evaluation of different methods. Species involved black locust, sessile oak, Scots pine, white poplar, E. beech, E. hornbeam, black cherry, sweet chestnut, black poplar, silver birch and E. larch: these species are either important Hungarian industrial wood species yielding large amounts of bark by-products or species which have not been investigated yet.
Apart from E. hornbeam and E. beech the inner and outer bark were both investigated. Bark samples were extracted by ultrasonication using methanol:water 20:80 v/v% solution. Antioxidant capacity was determined using the DPPH- (2,2-diphenyl-1-picrylhydrazyl), FRAP- (ferric reducing ability of plasma) and ABTS- (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) assays. Polyphenolic composition was measured by the Folin-Ciocâlteu method (total polyphenol content), by the total flavonoid assay and by the total flavan-3-ol assay.
As a rule of thumb, at least three antioxidant capacity assays should be run to assess the antioxidant properties of plant extracts, as none of the currently applied methods are suitable alone to determine the overall antioxidant capacity. This is, because each assay is specific to certain types of antioxidants, thus none of the methods sufficient to measure the overall antioxidant power of all compounds found in a plant extract. Because of the different selectivity of each method, information on the overall antioxidant power of the samples or of individual compounds can be obtained only by the combined evaluation of different assays (Hofmann et al. 2017). This was achieved in the present work by introducing a scoring system which combines the results of the DPPH, FRAP and ABTS antioxidant assays. This combined multiassay approach (CMA) was set up as follows: samples were ordered according their antioxidant capacity value within each assay, then score 1 was assigned to the highest antioxidant capacity and score 0 was given to the lowest antioxidant capacity sample, within one assay; to the samples with intermediate antioxidant capacity values scores were assigned proportionally in the range [1;0]. Finally, scores were summed for each sample. Theoretic maximum score was 3 (when sample has the highest antioxidant capacity with all of the 3 methods). Table 1. indicates the scores as well the results on polyphenolic composition.

Table 1. Left: Evaluation of the antioxidant capacity of the samples basing on a scoring system, combining the results of the DPPH, FRAP and ABTS assays sample-wise. Maximum score: 3. Right: Total polyphenol, flavonoid and flavan-3-ol contents of the samples. -: not detected, Q: quercetin, C: (+)-catechin.

Species	Inner bark	Outer bark	Total polyphenols (mg Q/g d.w.)		Total flavonoids (mg Q/g d.w.)		Total flavan-3-ols (mg C/ g d.w.)	
			Inner bark	Outer bark	Inner bark	Outer bark	Inner bark	Outer bark
Black locust	0.79	1.15	9.90	29.4	-	-	-	-
Sessile oak	1.57	1.28	46.2	71.6	-	-	-	-
Scots pine	1.66	0.80	76.2	16.4	-	0.42	21.6	3.05
White poplar	1.36	1.46	44.1	49.2	-	-	-	-
European beach	1.33	-	42.7	42.7	-	-	-	-
European hornbeam	1.24	1.24	25.2	25.2	0.39	1.48	0.39	0.39
Black cherry	2.92	1.43	139.0	70.0	3.71	2.49	61.8	19.5
Sweet chestnut	2.22	2.55	61.4	89.0	1.30	4.81	2.48	0.77
Black poplar	0.16	0.63	36.3	52.8	0.74	1.92	1.60	1.42
Silver birch	1.72	1.21	76.6	57.3	-	-	14.7	8.88
European larch	2.22	2.15	107	121	-	-	32.0	20.0

According to the CMA evaluation the samples with the highest overall antioxidant capacity were the inner bark of black cherry and the outer bark of sweet chestnut. The inner bark of cherry contains large amounts of flavan-3-ol type compounds, possibly responsible for the strong antioxidant effects. In the outer bark of sweet chestnut it is not the flavonoid and flavan-3-ols but possibly other types of polyphenols (e.g. tannins) which are responsible for the excellent antioxidant properties. According to the results, the presented CMA evaluation is suitable for tracking complex antioxidant properties in wood bark, and can be also applied to other tissues such as cones or leaves. Samples with highest values need further evaluations for possible uses in the future.

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Fractioning of native oak into lignocellulosic materials as an alternative for a sustainable forest management

Sebastián Barriga, Leyre Sillero, Jalel Labidi, Eduardo Robles

[1] Biorefinery Processes Group, Chemical and Environmental Engineering Department, Engineering Faculty of Gipuzkoa, University of the Basque Country UPV/EHU, SPAIN

Keywords: cellulose nanofibers, lignin, hardwood

ABSTRACT

Basque forests have switched from a traditional composition of mixed wood to predominantly pine forests, however, in recent years, government efforts have promoted the perseverance of native forests as an attempt to keep the native species opposed to traditionally exploited species. In this sense, the exploitation of native forests has supposed a challenge for local business as well as for a research centers and academic units. The need for innovative products from fewer resources to help reducing the pressure on forests is attracting the attention of the scientific community to provide value-added products from wood-based materials from native forests. In this work, the raw material was selected from the most abundant native species (*Quercus robur*) which was submitted to an industrial pulping consisting of a sodium hydroxide (15% w/w) treatment inside an autoclave for 90 min at 120 ºC. The obtained pulp was submitted to a sequence of bleaching treatments consisting in a sodium chlorite treatment and a peroxide hydroxide treatment. Sodium chlorite bleaching was performed for 2 hours at 75 ºC inside a water bath. On the other hand, the hydroxide peroxide bleaching treatment was performed using 1 g of sodium chlorite, 2 g of hydroxide peroxide, 0.5 g of pentetic acid (DTPA) and 2 g of $MgSO_4$ in a water bath for 150 minutes at 70 ºC. The lignin precipitation was done by stabilizing black liquor pH to 2 drop wise with $H2SO_4$, after which precipitated lignin was filtrated with a polyamide filter (0.2 µm pore) and a No. 3 sintered glass Buchner filter, washed with acidified water and dried at 50 ºC during 24 h. On the other hand, cellulose nanofibrils were made by passing the cellulose suspension through a Niro Soavi high pressure homogenizer.

The obtained lignin and CNF were analyzed by standard methods, resulting in competitive products compared to industrially obtained lignin and CNF from diverse raw materials, thus giving a value added application to native forests from the Basque Country.

Microwave Hardwood Modification Application for Fast Lumber Drying (Technical-Economic Assessment)

Alexandra Leshchinskaya

Plekhanov Russian University of Economics. 36 Stremyannyy Pereulok, 115093 Moscow, Russia

[e-mail: alixfl@mail.ru]

Keywords: economic advantage, hardwood, microwave wood modification, specific cost, timber drying.

ABSTRACT

Timber industry has permanent problems with hardwood drying: very long drying times, drying defects, and large material losses after drying, high energy consumption, expensive drying processes. Drying is the most energy intensive and, therefore, most costly step in lumber processing. Microwave (MW) wood modification can solve many wood drying problems. MW pre-treatment increases the permeability of the green wood, overcoming the propensity of the lumber to collapse during kiln drying and provides an opportunity for fast kiln drying immediately after sawing.

MW hardwood lumber pre-treatment provides following benefits for sawmills: 25-30 % increase in throughput, 30-40% reduction in required drying equipment, reduction in lumber losses by 3.5- 4.5%, up to 7% increase in production of higher quality boards, energy reduction for kiln drying by 30 %, cost reduction, improved environmental performance due to reduction in VOC (volatile organic compound) and fuel usage (COMPERE 2005).

The MW plant power required for sawmills with throughput 10,000m^3/y is 135 kW, 20,000 – 270 kW, 30,000 – 400 kW, 40,000 m^3/y – 540 kW at frequency 0.915-0.922 GHz.

Results of cost analysis for MW lumber pre-drying treatment (Fig.1) is given for the following conditions: MW plant outputs: 10,000; 20,000 and 30,000m^3/y at 6,000 working hours per year (3 shifts per day); MW plant costs at output 10,000 m^3/y - US$ 400,000, at 20,000 - $660,000, at 30,000 – $840,000; MW plants work automatic or with operator (one worker per shift); electric energy consumption 98 kWh/ m^3; electricity cost range US$0.06/kWh to $0.18/kWh; depreciation rate 17%.

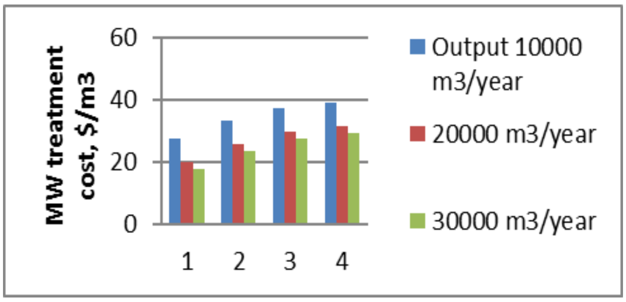

Figure 1. MW lumber pre-drying costs depending on plant output and electricity costs. One plant operator per shift, three working shifts per day. Electricity cost: 1 - US$0.06/kWh, 2 - $0.12/kWh, 3 - $0.16/kWh, 4 - $0.18/kWh.

If MW plant is used only 2 shifts per day the costs of MW processing increase by 13 to 21%. For MW plant operated by a worker the increase of the electricity costs doubles (from $0.06/kWh to $0.12/kWh) leadings to an increase of MW pre-drying treatment costs by 15 to

25%. MW automatic plants compared to plants with operators provide a MW treatment specific cost reduction at output 10,000 m^3/year by 18-26%, at 20,000 m3/y by 11-18%, and at 30,000 m^3/y by 8-13%.
Calculations showed that MW pre-drying treatment costs for automatic plant with output 20,000 m^3/year at electricity costs AU$0.06/kWh to AU$0.18/kWh grows from $16.4/$m^3$ to AU$28.2/$m^3$ at three working shifts per day and from $20.6/$m^3$ to $32.3/$m^3$ at two working shifts per day.
The electricity costs in the range $0.12 - $0.16/kWh form the largest portion of the total costs 35 to 57%, capital costs form17 to 21% of the share and labour costs form 9 to 14% of the share.
The economic study of new MW technology benefits in different conditions has been done for two species for which the drying process is difficult and costly. Specific costs of MW hardwood lumber pre-drying conditioning in the sawmill output range 10,000 to 30,000 m^3/year depend very significantly on electricity costs and varies from US$ 15.4 to $45.4/$m^3$ in the range of the electricity prices US$0.06/kWh to $0.18/kWh.
The study of new MW technology benefits in different Russian conditions has been done for two species for which the drying process is difficult and costly: hardwood - oak (*Quercus robur* L.) and softwood - larch (*Larix sibirica* Ldh.). Lumber prices used in the study are from the document "Sawmilling and wood wastes" (WOODWORKING INDUSTRY 2018). Lumber production sawmill output was in the range 10,000 to 30,000 m^3/y. It was found that increase in lumber recovery after MW conditioning provides savings of US$36.5 to $41.3/$m^3$ for hardwoods (oak) and US$29.3 to $37.6/$m^3$ for softwoods (larch). The increase in production of higher quality sawn timber can provide savings for hardwoods US$8.4 /$m^3$ and for softwoods US$ 6.3/m^3. Furthermore, savings connected with reduction of energy consumption (electricity and natural gas) for drying form US$2.2 - $2.6/$m^3$.
After withdrawing costs connected with MW treatment, the new technology benefits are: at sawmill output 10,000 m^3/y – US$8.4 – $21.4/$m^3$, 20,000 m^3/y – US$12.5 – $25.5/ m^3, 30,000 m^3/y – US$13.5 – $26.5/$m^3$ (at electricity costs $0.12/kWh, 3 working shifts per day, automatic MW plant). Additional benefits such as sawmill throughput increase, opportunity to dry larger cross section lumber and improved environmental performance due to reduction in VOC (volatile organic compound) and fuel usage can be assessed only in individual sawmill conditions.
New microwave technology application provide high economic advantages in timber industry and is recommended for commercialisation. The technology is not limited by sawmill throughput and could be implemented using existing kiln drying facilities.

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Determination of the cutting power in processing some deciduous wood species

Valentin Atanasov[1], Georgi Kovatchev[2]

[1]10 Kliment Ohridski Blvd., 1797 Sofia, Building A, office 435, Bulgaria, University of Forestry, Faculty of Forest Industry, e-mail: vatanasov_2000@ltu.bg

[2]10 Kliment Ohridski Blvd., 1797 Sofia, Building A, office 435, Bulgaria, University of Forestry, Faculty of Forest Industry, e-mail: g_kovachev@ltu.bg

Keywords: wood milling, milling machine, deciduous wood, power-energetic indicators

ABSTRACT

Experimental results in longitudinal milling of deciduous wood test samples, which are used in the production of valuable frame furniture – Meranti (*Shorea leprosula*) and Koto (*Pterygota macrocarpa*), are presented in the study. As an experimental unit a universal milling machine *FD*-3 (Bulgaria) was used. It is located in the *Woodworking Machines Laboratory*, University of Forestry – Sofia. The influence of some important factors on the cutting process was reported – feed speed *U* and area of cutting *A*, over the input power of the cutting mechanism and hence on the cutting power N_c. An analysis of the results was carried out.
Cutting power is an indicator that is determined when calculating the cutting modes of the technological machines, including woodworking. There are a number of factors that influence it – one of them is the wood species. On the other hand, there are a number of studies in the literature that relate mainly to the influence of the cutting tool parameters, heat treatment of wood, cutting modes, etc., on the power-energetic indicators of circular, milling and sanding machines in processing of widespread wood species such as Scots pine (*Pinus sylvestris L.*), beech wood (*Fagus sylvatica L.*) etc. (Gochev et al. 2018, Kubš et al. 2016, Barcík et al. 2008, Kováč and Mikleš 2010). On the basis of the conducted literary research, the aim of this study is to determine the influence of the feed speed and the area of cutting on the cutting power when milling some valuable wood species.
A groove cutter with a diameter of 140 mm was used as a cutting tool. The test samples are details with a cross-sectional dimension of 50x50 mm and a length of 1000 mm. Some of them can be seen in Fig. 1. Their density ρ is determined by an electronic scale (*RADWAG WLC 1/A2*, Poland) and a caliper, and their moisture content *W* with a moisture meter (*Lignomat*, Germany). The results are: Meranti – ρ = 490 kg.m^{-3}, *W*= 13 %; Koto – ρ = 510 kg.m^{-3}, *W*= 12 %. Cutting power is determined by measuring the input power of the cutting mechanism in idle and working condition. For measuring it, the device shown in Fig. 2 (*US301EM – Unisyst Ltd.*, Bulgaria), a portable computer and software from the manufacturer were used.

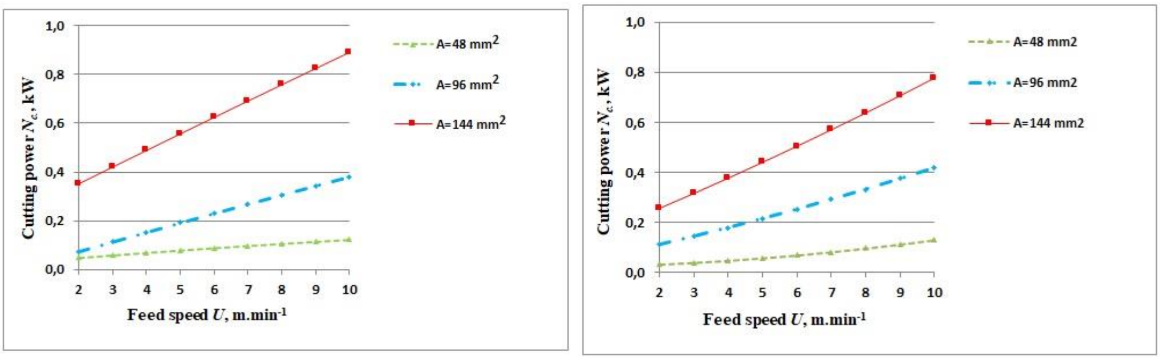
Figure 1: Test samples

Figure 2: Measuring device - model US301EM

Determination of the influence of feed speed and milling area was performed by conducting a planned two-factor regression analysis. The levels of variation of the studied factors in explicit form are $U(x_1)$ = 2, 6 and 10 m.min^{-1} and $A(x_2)$ = 48, 96 and 144 mm^2. In coded form they are -1, 0 and +1. The total number of conducted experiments with combinations of factors is 9.
The results are calculated with the software products *QstatLab5* and *Microsoft Excel*. Accordingly, for the two wood species the following regression equations, which can be used for the analytical determination of the cutting power, were obtained:

- Meranti: $N_m = 0{,}230 + 0{,}153x_1 + 0{,}268x_2 - 0{,}003x_1^2 + 0{,}126x_2^2 + 0{,}116x_1x_2$; (1)
- Koto: $N_k = 0{,}252 + 0{,}154x_1 + 0{,}218x_2 + 0{,}012x_1^2 + 0{,}034x_2^2 + 0{,}105x_1x_2$. (2)

The regression coefficients of the obtained equations show that the factor X_2, which corresponds to the cutting area, has a greater impact in this study. This trend is almost equal for both wood species. Graphically, part of the results of the effect of feed speed on the cutting power are shown in Fig. 3: *A*– Meranti (*Shorea leprosula*), *B*– Koto (*Pterygota macrocarpa*).



A) *B)*

Figure 3: Influence of the feed speed on the cutting power in different areas of cutting: A – Meranti, B – Koto

ACKNOWLEDGEMENT

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Influence of the heat on the duration of curing adhesives for veneering

Vladimir Mihailov[1], Dimitar Angelski[2], Vasil Merdzhanov[3]

[1] University of Forestry –Sofia, Bulgaria, PhD student, vladko86mihailov@gmail

[2] University of Forestry –Sofia, Bulgaria, Assoc. professor, PhD, d.angelski@gmail.com

[3] University of Forestry –Sofia, Bulgaria, Assistant professor, PhD, vasilmerdzhanov@gmail.com

Keywords: veneering, urea-formaldehyde glue, veneering mode

ABSTRACT

Substantial changes have been made over the past decade over the chemical composition and formulations for the production of urea formaldehyde adhesives. These changes are primarily intended to meet environmental standards and reduce the release of free formaldehyde. All of this has a major impact on the process of bonding and veneering (ANGELSKI D. et al., 2009). In addition, the reduction of formaldehyde content in urea-formaldehyde adhesives directly affects on the bond strength and the duration of the polymerization. As is known, the heating temperature of the urea-formaldehyde adhesive, respectively, the temperature of the press plates is directly related to the duration of its application (KOLLMANN F. et al., 1975). The curing time of the adhesive is of particular importance for the ability to apply high performance bonding and veneering methods. On the other hand, the increased pressing time at an elevated veneer temperature (over 140 ° C) reflects negatively on the bonding strength and the moisture-thermal stability of the adhesive bond. From the economic and technological point of view, the duration of the veneering process is to establish the moment for the final bonding of the glue. The purpose of the study is to determine the minimum hardening (curing) time of urea formaldehyde adhesives at different heating temperatures.

Table 1: Indicators of the urea-formaldehyde adhesive

Indicators	Glue I	Glue II	Glue III
Dry matter content by 100 °C, %	72	70	70
Free formaldehyde content, %	0,9	0,8	0,85
Viscosity by 20 °C, mPa.s	2 500 ÷ 3 500	2 500 ÷ 3 000	2 000 ÷ 3 000
pH of 50 % aqueous resin solution, by 20 °C	8	7,5	7,5
Time of gelation by t - 20°C±1°C, h	1	1,3	1,5

The influence of the temperature of press plate on the curing time of three widely used in the art carbamide-formaldehyde adhesives is investigated. The conventionally used urea formaldehyde adhesives are indicated in study numbers I, II, and III. Table 1 provides information on their underlying indicators. The time required for the harden of the urea-formaldehyde adhesives was determined by the following method: the glue was spread on a 0.01 mm thick aluminum foil on a pre-sized area (0.0025 m^2) at a rate of 0.150 kg /m^2. The aluminum foil with the applied adhesive was attach tightly to the press plate, heated to a certain temperature. The final hardening of the adhesive (glue) is determined by mechanical regular pressure (over 5 seconds) on the adhesive film with a thin metal tip.

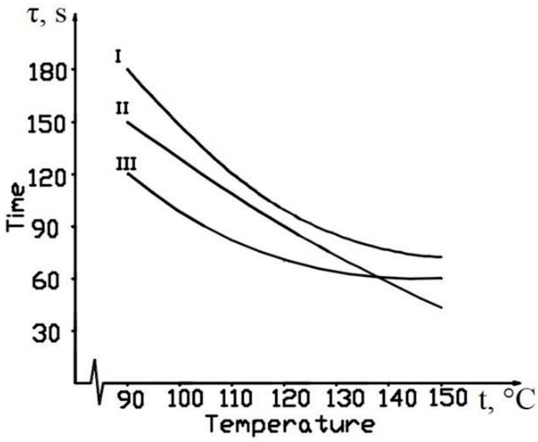

Figure 1: Relation between curing time of the adhesive and the temperature of press plate

On the basis of these, Figure 1 shows a graphical relationship between the curing time of the adhesive and the temperature of press plate in the temperature range (from 90 to 150 °C). The following major conclusions can be drawn from the study:
- The dependence between temperature and duration of curing of the adhesive has a different character for the investigated urea formaldehyde adhesives (glues).
- Reducing the free formaldehyde content of adhesives leads to a significant increase in the duration of their hardening (curing).

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Bending strength of High-Density Fibreboards (HDF) Manufactured from Wood of Hard Broadleaved Species

Julia Mihajlova [1], Viktor Savov[2]

[1] Bulgaria, University of Forestry, Sofia, e-mail: jmihajlova@ltu.bg

[2] Bulgaria, University of Forestry, Sofia, e-mail: victor_savov@ltu.bg

Keywords: bending strength, HDF, hard broad-leaved tree species, pressing pressure, phenol-formaldehyde resin content.

ABSTRACT

To produce HDFs, wood-fibre mass from wood of beech and Turkish oak has been used. The boards have been manufactured under laboratory conditions after dry method.
The summarized indicators for the density and the bending strength of HDFs in case of change in pressing pressure and PFR content according to the experiment plan are presented in Table 1.

Table 1: Results for the density and the bending strength of HDFs

No.	Pressing pressure *P*, MPa	PFR content P_x, %	Density ρ, kg.m^{-3}	Bending strength f_m, N.mm^{-2}
1	3.0	10	1003	30.04
2	4.0	10	1067	41.82
3	5.0	10	1116	46.74
4	3.0	12	1055	42.99
5	4.0	12	1065	49.71
6	5.0	12	1126	55.11

Under the experiment conditions, the bending strength of the boards varies from 30 to 55 N.mm^{-2}. I.e., this indicator improves, respectively increases, by 80%. Graphically, the relationship between the bending strength and the pressing pressure in case of boards with various participation of PFR is presented in Fig. 1.

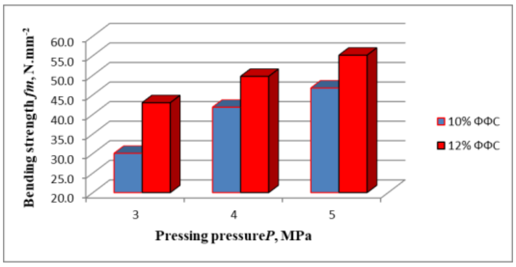

Fig. 1. Relationship between the bending strength of FBs and the pressing pressure and PFR content

In FBs with 10% PFR content, more significant increase of bending strength is observed in case of pressure increase from 3 to 4 MPa. Relatively lower is the improvement in case of pressure increase from 4 to 5 MPa. In FBs with 12% PFR content, with the pressure increase from 3 to 4 and to 5 MPa, uniform improvement of the bending strength is observed.
With a view to application of the various HDFs, the super hard ones should meet the requirements for boards with increased load-carrying capacity, and the very hard ones – the requirements for boards for bearing structures, Fig. 2 and Fig. 3. The respective strengths should be at least 42 N.mm^{-2} and 36 N.mm^{-2}.

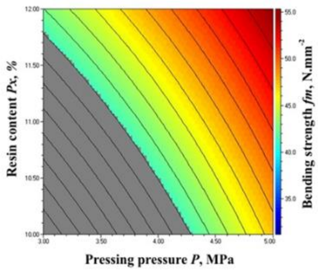

Fig. 2. Lines of constant levels for bending strength in case of super hard FBs with increased load-carrying capacity

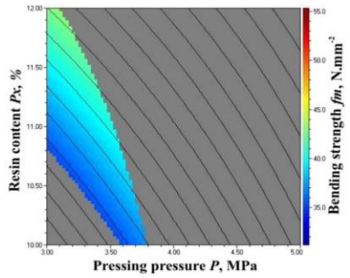

Fig. 3. Lines of constant levels for bending strength in case of very hard FBs for bearing structures

With a view to meeting the requirements for bending strength in super hard FBs, at 10% PFR content, the pressing pressure should be at least 4.3 MPa, and at 12% PFR content – at least 3.2 MPa.

To meet the requirements for bending strength in case of very hard FBs and 10% PFR content, the pressing pressure should be at least 3.6 MPa.

As a result of the performed investigation and analysis for the pressing pressure impact, within a range of 3 to 5 MPa, and 10% and 12% PFR content on the mechanical indicators of HDFs, the following main conclusions may be drawn:

1) In order to manufacture super hard HDFs, the pressing pressure should be at least 3.8 MPa at 10% PFR content and at least 3.2 MPa at 12% resin content;
2) With a view to meeting the requirements for bending strength in super hard FBs, at 10% PFR content, the pressing pressure should be at least 4.3 MPa;
3) With a view to meeting the requirements for bending strength in super hard FBs, at 12% PFR content, the pressing pressure should be at least 3.6 MPa.

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Occurrence of shake in oak (Quercus ssp.) and it's effect on flooring top-layer quality

Victor Grubîi[1], Jimmy Johansson[2],

[1] SE 351-95, Linnaeus University, Department of Forestry and Wood Technology victor.grubii@lnu.se

[2] Same for second author

Keywords: oak yield flooring wood cracks ring shake defects

ABSTRACT

Oak (Quercus ssp.) is generally preferred wood species as surface material in flooring products realization. The presence of defects such as cracks limits the utilization of the raw material and ultimately, limits the competitiveness of wood in the flooring market when compared to other materials.
The objective of this study was to develop the theoretical aspects for crack-type identification based on the appearance of the sawn top-layer lamellas and evaluate the influence of crack occurrence on the quality of flooring top-lamellas.
The results of this study provide an insight for crack-type identification on the surface of oak (Quercus ssp.) flooring top-lamellas and wood quality optimisation aspects.

Introduction

Cracks such as *heart, star and ring shake* are common for hardwoods e.g. oak (*Quercus* ssp.), maple (*Acer* ssp.), beech (*Fagus Sylvatica* L.), chestnut (*Castanea Sativa* M.). The presence of these shakes in the material for products such as solid or layered flooring is accepted only for the lowest grades and to a certain extent (SS-EN:14389 2017). Herein, most of the shake in oak (*Quercus* ssp.) is abiotically induced under factors such as wind and frost (Richter 2010). Therefore, their presence in the raw material represent an intrinsic condition and woodworkers must possess all the background knowledge for best material handling practices.
Wood products have a positive impact on human perception (Nyrud and Bringslimark 2010). Although, defects such as "big" and "dark" knots in contrast with the "light" and "warm" texture of the wood are generally seen as disturbing for the end-users (Broman 2000). Therefore, it can be induced that surfaces with large cracks filled by dark putty are rather undesirable to the human eye. Thereby, the aim of this study was to assess the presence of defects on oak (*Quercus* ssp.) flooring top-lamellas with the focus on ring and star-shake characterisation and its effect on the material quality.

Material and Methods

For this exploratory study, 16 oak (Quercus ssp.) 1-strip flooring top-layer lamellas were selected after the drying step in a running industrial production. The selection of lamellas was made randomly with the sole condition of defect presence. The lamellas had nominal dimension of 2400x225x4.5mm and were conditioned at ~7% MC. Lamellas were inspected on the external outer surface corresponding to a longitudinal-tangential (L-T) plane in wood. Knots, cracks (including shake) and other defects such as bark pockets and rot were manually measured and documented by type.

Results and Discussion

0Results of lamellas inspection show that, to some extent, it is possible to separate between different types of cracks based on the L-T section of wood. The two types of shake (ring and star-shake), have rather differently properties although in all three boards where ring-shake was detected, star-shake was present too. The vice-versa was not true. The specific of ring-shake is its extensive length along same annual ring followed by the wood discoloration in the zone adjacent to the crack, due to enzyme attack(Richter 2010). The star-shake in turn, crosses several annual rings, is shorter in length and wider due to the “opening” effect during drying. However, ring and star-shake in the studied oak lamellas were not the only sources of lamellas degrading (fig.1). In a quarter of lamellas, end-cracks were the grade-determining factor. This is due to cracking of weak material close to pith and association of the heart shake defect. However it can not be said that all end-cracks were heart shakes since the position of lamellae within the log is unknown and in most cases end-cracks are believed to be triggered by the tangential shrinkage strain (Niemz 1993). Bark, rot and loose dead knots accounted for 30% of the degraded lamellas and are associated with poor forestry operations. Drying checks and fresh-knot cracks can be attributed to the material mishandling errors and accounted for 18% of the inspected lamellas. The mean length of the most significant cracks in oak are presented in fig.2. As it can be observed, ring-shake is by far the most severe defect and future studies must evaluate the best material handling practices regarding this defect. Yet, this study represents an initial attempt to quantify the occurring defects in oak. Future studies should ascertain a statistical validation of the observations and develop methodologies for visual grading systems with crack type identification.

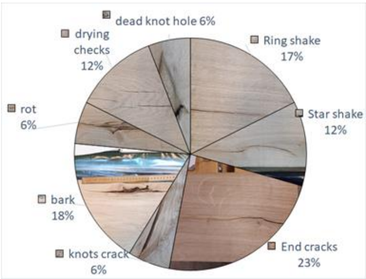

Figure 1. Distribution of downgraded oak lamellas for flooring top-layer as function of defect type

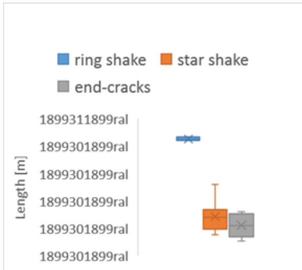

Figure 2. Crack length in oak flooring lamellas as function of crack-type

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The importance of forest management history in life cycle assessment (LCA) scope definition for currently harvested birch trees in Latvia

Edgars Kuka[1]*, Dace Cirule[1], Bruno Andersons[1]

[1] Latvian State Institute of Wood Chemistry, Dzerbenes street 27, Riga, Latvia.

*E-mail: kukinsons24@gmail.com

Keywords: Life cycle assessment, environment, system boundary, birch, roundwood production, LCA, forest management.

ABSTRACT

Life cycle assessment (LCA) is a valuable tool to investigate the environmental load of a product over its life cycle. Because of the environmental problems that the world is facing now the use of LCA is becoming more attractive. Forests play an important role in protection of environment and especially the global carbon cycle – acting as a sink for atmospheric carbon dioxide and providing long-term carbon storage (INNES 2009). However, also sustainably managed forests are not carbon neutral, because of the forest cultivation activities that are applied during the life cycle of the fully-grown trees. These activities (fertilization, planting, thinning etc.) involve the use of fossil fuel consuming devices, the use of electricity and different chemicals. Therefore, the effect is not only on global warming, but also on eutrophication, acidification and photochemical oxidant formation (GONZALEZ-GARCIA ET AL. 2014). Most of the published studies related to LCA are calculating the environmental impacts for the “future” trees that are planted now and will be harvested after several years. For calculations they are using current forest management methodology, devices and data, however in such a long period of time some aspects in forest management practice can significantly change, which can change the environmental load of a harvested tree as well (MICHELSEN ET AL. 2008, GONZALEZ-GARCIA ET AL. 2009). For the trees that are harvested currently the situation should significantly differ from the “future” trees, because these trees were planted several years ago when the forest management was less mechanised and developed. Therefore, LCA for currently harvested trees should be conducted by using information from sources which describe the forest management history in the specific region. The main goal of the present study was to determine which forest management processes should be included in the LCA for the currently harvested birch trees in Latvia and how they differ from the birch trees that are planted now and will be harvested in the future.

According to the legal acts of the Republic of Latvia the final felling of birch trees is permitted when the age of trees reaches 51-71 years depending on the site index. Hence birch trees that have reached the final felling age and are currently harvested started their life cycle in 1950s. At that time most of the forest managing operations that are in practice nowadays were not used or they involved non-mechanised equipment which can be excluded from the LCA system boundary because of the marginal impact on the environment. Production of birch roundwood includes four subsystems (Fig. 1): seed production, seedling production, silvicultural operations and logging operations. All subsystems should be included in the system boundary for currently planted trees because most of the processes are mechanised and/or involve usage of different chemicals (fertilizers, repellents etc.). By analysing forest management history in Latvia, it was possible to determine the system boundary for currently harvested birch trees. The results showed (Fig. 1) that the seed and seedling production should not be included because at that time part of the birch forests regenerated naturally and others artificially by sowing without the

use of mechanised equipment. Similar situation is for silvicultural operations, where only the first mechanised equipment in Latvia for these purposes was introduced at the end of 1970s. The results suggest that the only subsystem which should be included in the LCA of currently harvested birch trees (roundwood) is logging operations.

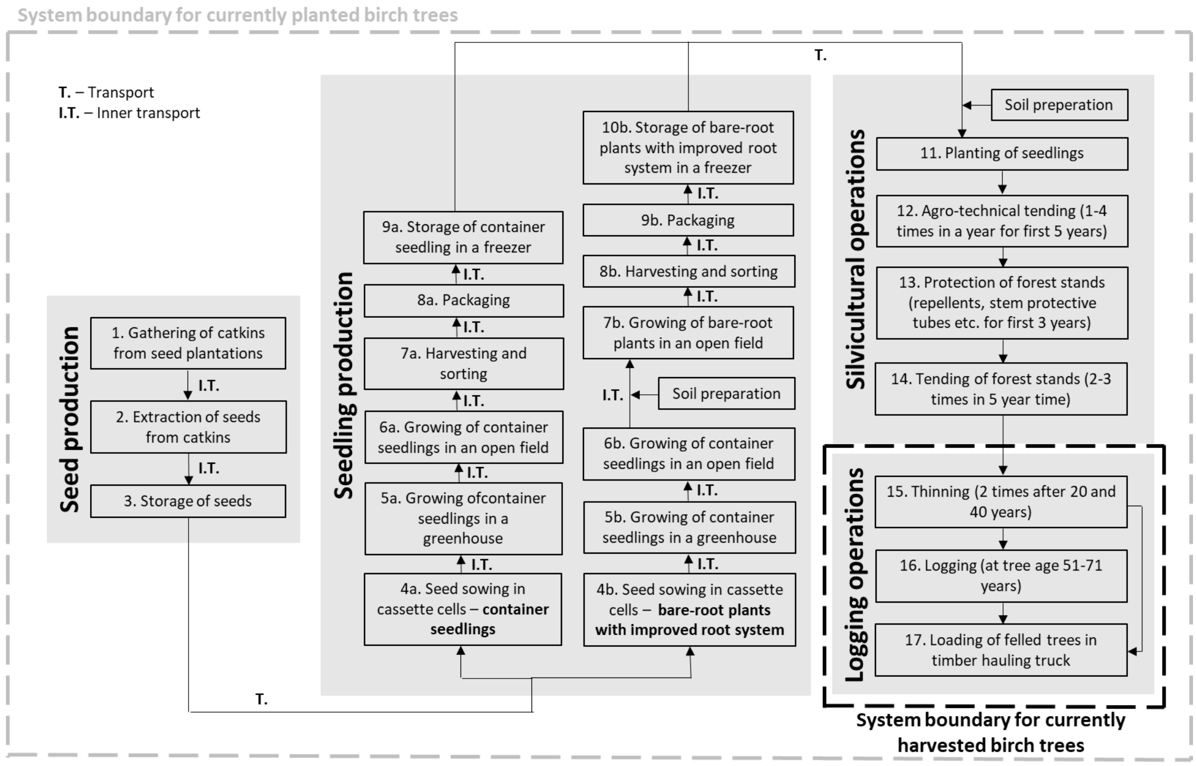

Figure 1: Subsystems included in the process chain of birch roundwood production in Latvia: system boundary for currently planted birch trees (gray dashed line) and for currently harvested birch trees (black dashed line)

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The influence of saw setting and tensing on quality of beech bandsawing

Bartosz Pałubicki [1], Mariusz Horała [2]

[1] Poznan University of Life Sciences, Faculty of Wood Technology, Dept. Of Woodworking Machines and Basis of Machine Design, ul. Wojska Polskiego 38/42, 61-627 Poznań, Poland, email: bpalubic@up.poznan.pl

[2] Zakład Stolarski Mirosław Horała, Ługi 10, 63-130 Książ Wielkopolski, Poland

Keywords: wood sawing, primary wood processing, beech, bandsawing, saw set

ABSTRACT

The quality of bandsawing depends on many factors such as wood species, state of the bandmill, tool preparation and tensioning, kinematic parameters of process etc. This work deals with two parameters: spring-set of tooth and tensioning of the band. It may be concluded that for beech wood better surface quality was obtained by the saw with higher saw set and lower tension. Fractions of sawdust are also correlated to tension of saw blade and saw set.

Introduction

Despite of many years of utilization of bandsawing in primary wood processing it still causes many troubles in yield-quality domain. Acceptable quality with reasonable productivity depends on simultaneous assuring appropriate values for numerous parameters (BARCIK S. 2003): tool, machine, machine-tool interaction and process parameters chosen for specific wood type, moisture content, temperature etc.

It is known (SIKLIENKA AT AL. 2015) that stellit teeth tips gives better quality than swaged ones. Spring-set saws produce the worst quality of all, but they are widely used because of inexpensiveness and easy of service.

In present work the influence of saw set and band tensing in the machine on sawing quality are examined.

Materials and methods

Two sharp narrow bandsaws were used in experiment having equal parameters as follows: width 40mm, thickness 1.25mm, length 4800mm, pitch 22.2 mm, tooth height 7 mm, clearance angle 30°, sharpness angle 50°, rake angle 10°, sharp. Teeth of both saws were spring-set in the pattern: left-straight-right-straight, but with different saw set (side clearance): $\mathbf{s_1=0.57}$±0,02 mm for first saw and $\mathbf{s_2=0.47}$±0,03 mm for the second.

The machine used in experiments was horizontal band sawing machine with moving support Wirex CZ-1 (polish production).

A log from freshly cut beech (*fagus silvatica*) tree of c.a. 40 years old was equalized to the 20cm wide prism and then subjected to cutting into timber.

The wood was cut with constant process parameters: cutting speed 23 m/s, feed per tooth 0.09 mm, however 3 levels of saw tensioning were applied: 49, 74 and 99 MPa.

The quality of cutting was described by surface roughness and sawdust length fractions. Surface roughness was measured with use of a Carl Zeiss Jena surface analyser equipped with measuring stylus tip of 10±2.5 µm radius and nose angle of 90˚. The feed rate during measurements was equal 200 µm/s. The obtained results were filtered according to EN ISO 16610-21:2012 standard. Total pathway of 55 mm were measured for each sample and divided

into 5 unit lengths (12,5 mm) for which the mean roughness depth (R_z) was calculated with elementary sampling length 2,5 mm.
Saw dust dimension analysis were performed with optical method according to PAŁUBICKI AND ROGOZIŃSKI 2015.

Results

From the figure 1 it is visible that generally for higher saw set a better surface quality (lower roughness) has been achieved. The saw tension increase in studied cases lead generally to worse quality of surface.

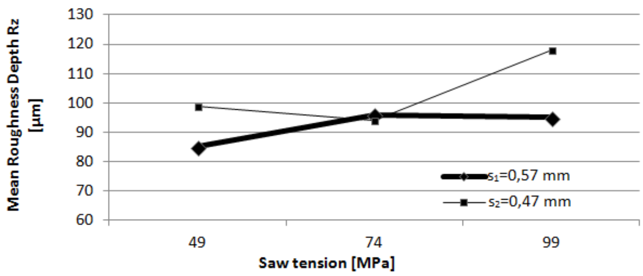

Figure 1: Mean roughness depth Rz of surfaces created by sawing with variable saw tension for saw set s1=0,57 mm and s2=0,47 mm

The finest sawdust (<125 µm) fraction seem to have similar trends to surface roughness – for higher Rz more small particles exist (fig. 2). Better surface quality is connected with higher fraction of medium particles (126-250 µm). Fraction of bigger sawdust particles (251-500 µm) is well correlated to the saw set – higher the saw set more big particles produced.

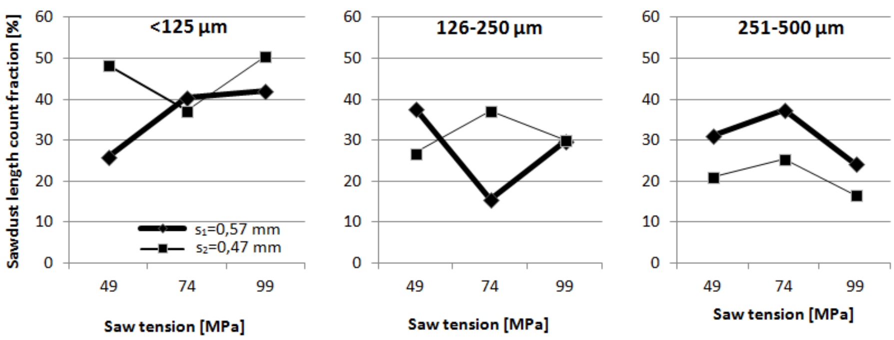

Figure 2: Count fractions of sawdust length (<125 µm, 126-250 µm and 251- 500 µm) with variable saw tension for saw set s1=0,57 mm and s2=0,47 mm

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Parallel Session I.
Silvicultural aspects and material properties of hardwoods

Research Findings of High Quality Timber Producing Black Locust Breeding Activities

István Bach[1], Bálint Pataki[2], Jenő Németh[3], Sándor Horváth[4], Kálmán Pogrányi[5], Márton Németh[6]

[1] University of Sopron, Faculty of Forestry, Hungary, Sopron, bachistvandr@gmail.com

[2] Hungaroplant Kft., Hungary, Budapest, balint.pataki@silvanus.hu

[3] Hungaroplant Kft., Hungary, Budapest, silvanus.jeno@gmail.com

[4] University of Sopron, Faculty of Forestry, Hungary, Sopron, horvath.sandor@uni-sopron.hu

[5] Hungaroplant Kft., Hungary, Budapest, kalman.pogranyi@gmail.com

[6]Silvanus Forestry Kft., Hungary, Budapest, marton.nemeth@silvanus.hu

Keywords: black locust, clonal variety, breeding, quality timber, apiary, fertilization

ABSTRACT

Based on the areas afforestated with Black Locust (appx. 450.000 ha) and its annual felling yield (appx. 2 million m^3) *Robinia pseudoacacia L.* is one of the most important tree species in Hungarian forest management. Due to changing, warming climate conditions there is an increasing need to utilize otherwise unusable land, for which Black Locust is perfect due to its extreme tolerance to bad quality soil and low precipitation. In the European context Hungary is the most important *Robinia* breeder with regard to the related research activity and therefore Hungary is recognized as a world leader.

At the same time, our Black Locust products are also of vital importance. It is noteworthy to mention perhaps the most important one of these, which is Black Locust honey, as the already existing Black Locust forests provide a unique opportunity for beekeepers. The revenue arising from the production of Black Locust honey is the most important side revenue stream besides the sale of the actual hardwood.

It is therefore expedient to carry out the breeding of the Black Locust variety via complex research methodologies. Based on a synchronised methodology in a coordinated experimental system, it is possible to produce fast growing and high yielding varieties already at a young age which are not only outstanding for the production of quality industrial hardwood, but also for beekeepers due to their high nectar yield and prolonged flowering. Preparation for the cultivation of multi-purpose variety candidates has a special importance and therefore an essential future research objective is to develop cultivation technologies, particularly for fertilization.

There is a comparative trial near Csemő in Pest county, which has been established as a part of a former research project in 2014. The results of the juvenile stand are illustrated in the graph below.

Besides the favorable stem quality of the varieties the estimated yield – with 1.500 trees/ha – is more than 150% of the control (seed stand seedlings) yield.

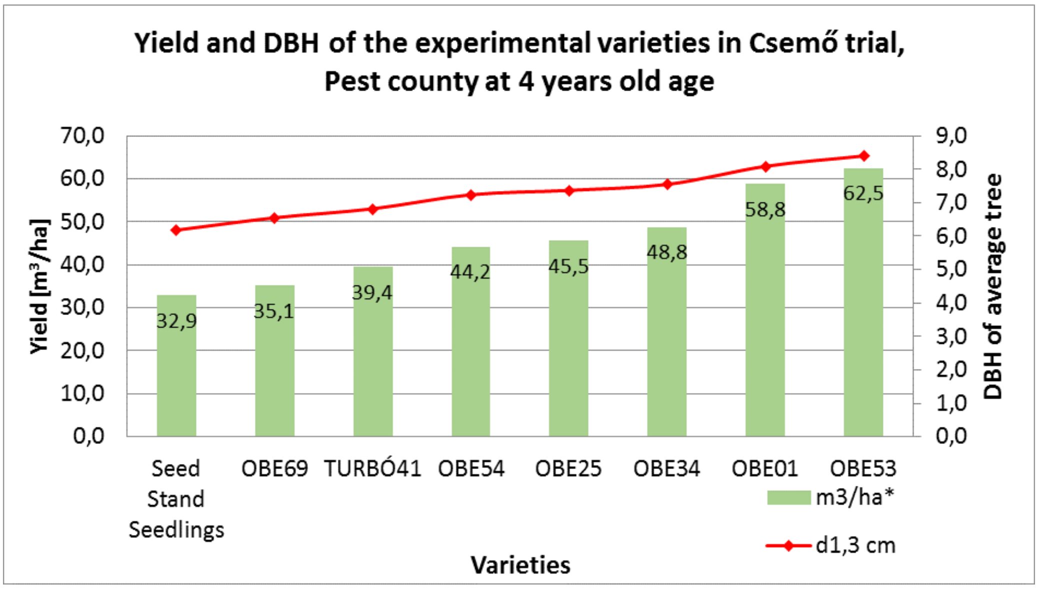

Figure 1

The objective of the research process is to breed new varieties with excellent yield parameters whilst also extending and delaying the blooming period and increasing nectar yield. Through this research, honey production can be made more economical with its rich, late and prolonged flowering.

In order to achieve these objectives, within the framework of the above-mentioned complex breeding methodologies and within the VEKOP-2.1.1-15 and VKE-17 projects, test plantations were established with these special varieties in Ócsa, Újhartyán, Tápiószele, Monorierdő and Pilis villages. The test plantations consist of 2-3 repetitions with double-factor randomized blocks, fertilization (organic and fertilizer treatment) being a second factor. The results of these experiments will give the basis for further variety selections.

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Living with ash dieback - Silviculture systems for Irish ash

Ian Short[1], Jerry Hawe[2]

[1] Teagasc Forestry Development Dept., Ashtown Research Centre, Dublin 15, Ireland, Ian.Short@teagasc.ie

[2] Forestry Consultancy & Research, Belfast, Northern Ireland, jerryhawe@gmail.com

Keywords: *Fraxinus excelsior*; *Hymenoscyphus fraxineus*; Management; Restructuring;

ABSTRACT

Ash (*Fraxinus excelsior*) is the most common broadleaf high forest species in Ireland. It is also one of the most important native woodland species and forms a key component in the wider cultural landscape. Ash accounts for over 3.2% of the forest estate in Ireland (approx. 21,000 ha). Over 17,000 ha of ash plantation has been established, on open-field sites, since 1990. This represents a major investment both from a landowner and state perspective. These plantations are almost exclusively monoculture ash and, being relatively young, are very susceptible to ash dieback (*Hymenoscyphus fraxineus*). It was first confirmed in Ireland in 2012. Initially an all-Ireland eradication policy was instigated in an attempt to control the spread of the disease. However, given the experience in neighbouring countries and the latest scientific advice, eradication in Ireland is no longer considered feasible. Policy reviews in Ireland broadly propose a move toward trying to manage and minimise the impacts of the disease. This will require support and advice to forest owners regarding appropriate silvicultural interventions. The general experience and research findings from Great Britain and continental Europe would broadly suggest a twofold approach to managing the silvicultural and ecological impacts of the disease. Management interventions should aim to promote: 1.) The general health, vigour and therefore longevity of the existing ash stand; and 2.) Greater species diversity with a view to building increased resilience. Where feasible, conventional thinning may promote the health and vigour of selected trees, which over time may secure a greater timber income for the forest owner. It may also preserve the ecological integrity of the woodland during the transition to a more mixed species stand. Retaining relatively healthy trees for as long as possible may also promote the species natural resistance to the pathogen. Proactively developing species diversity, particularly in Ireland's relatively young, monocultural and structurally homogenous ash plantation resource, is likely to require adapted thinning interventions whereby group and other shelterwood systems facilitate admixing. This paper presents some case-studies of possible silvicultural options for the management of ash dominated woodlands in Ireland. The majority of the Irish forest industry utilises the clearfell system with subsequent replanting. Until recently, the eradication policy for ash dieback included the clearfelling of any plantation confirmed to have the disease and then subsequent replanting with alternative species (Fig. 1A). The recently established Irish ash plantation resource has recognised thinning guidelines (see SHORT AND RADFORD 2008) that are generally a combination of rack and selection thinning, designed to provide permanent access to the plantation and to promote rapid growth of approx. 300 selected trees ha^{-1}. Some of the proposed silvicultural options below are intended to be superimposed with the rack and selection thinning. All of the proposed systems aim to take advantage of the nursing effect provided by the ash to be replaced, rather than planting into an open-field situation following a clearfell operation if restocking is required. The following systems will be outlined and case-studies of their use in Ireland presented.

Free-growth / Halo thinning

Free-growth, or halo thinning, entails the selection of vigorous, healthy trees and the removal of all surrounding crown competitors (Fig. 1B). A case-study from Ireland will be presented.

Systematic thinning with underplanting

This involves the felling of two or three lines and replanting with alternative species (Fig. 1C). A case-study from Ireland with replanting with alder (*Alnus glutinosa*) will be presented.

Selection with small coupe felling

This involves conducting a rack and selection thinning but also felling small coupes (0.025 – 0.045 ha in size) and replanting with alternative species (Fig. 1D). A case-study from Northern Ireland with replanting with native oak (*Quercus robur*), birch (*Betula pubescens*) and hazel (*Corylus avellana*) will be presented.

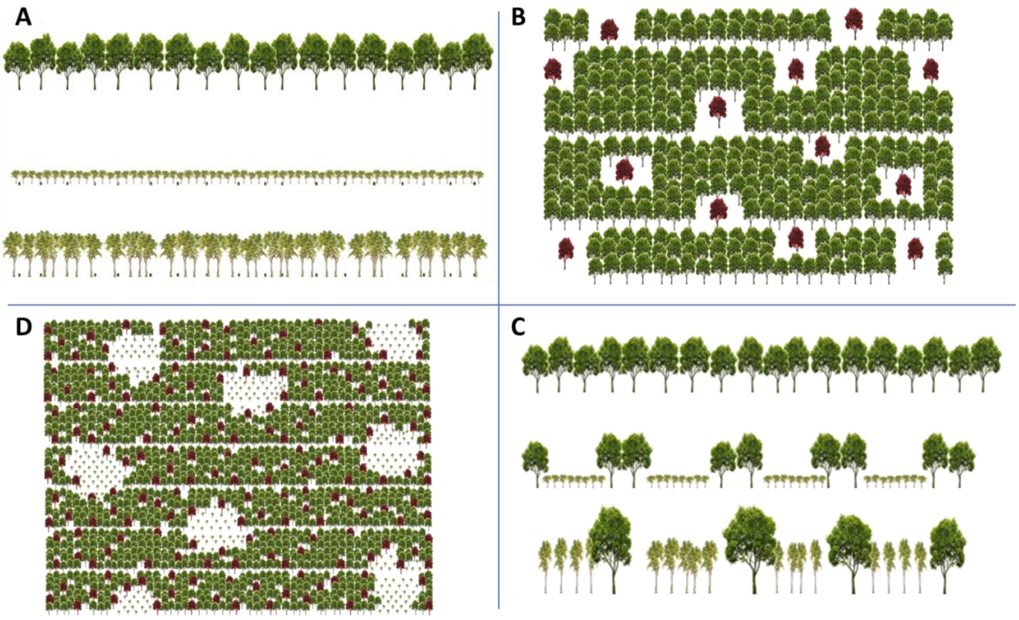

Figure 1: Silvicultural systems for management of ash in Ireland. Clockwise from top left: A) Clearfell and restock; B) Free-growth; C) Systematic thinning with underplanting; D) Small coupe felling

Potential positives from ash dieback?

The advent of ash dieback in Ireland will likely have severe consequences to the Irish landscape and implications for a developing native hardwood industry, but some positives may also occur. Improved, site specific, silviculture may develop and become more prevalent, replacing the currently predominant monoculture / clearfell practices, and thereby increase species and structural diversity and resilience to pests, diseases and changing climatic conditions. In contrast to open-field afforestation, the growth of broadleaves in uneven-aged woodland based systems may have positive implications for future hardwood stem quality.

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Potential of short-rotation aspen and willow biomass for novel products in bioeconomy: a demonstration project "AspenWill"

Rytkönen Peetu[1*], Viherä-Aarnio Anneli[1], Hyväluoma Jari[2], Rasa Kimmo[1], Suhonen Heikki[3], Beuker Egbert[1], Möttönen Veikko[1], Jyske Tuula[1]

[1*] Natural Resources Institute Finland (Luke), Production Systems Unit, peetu.rytkonen@luke.fi

[2] Natural Resources Institute Finland, Natural Resources Unit

[3] Department of Physics, University of Helsinki, Finland

Keywords: aspen, biochar, biocomposite, fibres, 3D imaging, *Populus*, *Salix,* pore structure, willow, wood structure

ABSTRACT

Hybrid aspen and willow are the fastest growing tree species in Finland. Hybrid aspen yields reach up to 20 m^3 ha^{-1} per year in about 25 year rotations. The species show excellent coppice vigour that enables even higher second rotation growth. For willows in Finland, dry mass production >13 t ha^{-1} per year has been reported in about 5 years rotations.

Novel bioeconomy approaches call for more and faster production of lignocellulosic biomass and its better-tailored use for higher added-value. High-yield capacity and structural and chemical properties of aspen and willow indicate their excellent potential for design applications, for example production of designed biochar and high-quality biocomposites.

Hybrid aspen and willow are cultivated in clonal plantations. This allows for easily and quickly improving wood quality traits, or introducing new traits through breeding and selection. However, we lack crucial knowledge about the genetic variation in several quality traits of woody biomass between and within the aspen and willow species. No knowledge exists on interlinkages between the raw-material quality of short-rotation species and properties and functionalities of novel end-products.

In this demonstration study, we aim to address the following research questions (Figure 1):

1) What are the key structural and chemical traits of aspen and willow woody biomass in producing novel end-products, namely a. design biochar, and b. novel biocomposites?
2) How do the raw-material characteristics affect the properties and functionalities of design biochar and innovative light-weight biocomposites?
3) How the novel uses of willow and aspen biomass should direct the future tree breeding strategies?
4) How the research knowledge can be best utilized to promote research and development of wood working entrepreneurs?

For a pilot study, five hybrid willow clones (hybrids of *Salix schwerinii*, pollinated by: *S. cv. Aquatica*, *S. myrsinifolia*, *S. phylicifolia*, and *S. viminalis x S. x* d*asyclados*), originating from a past energy willow hybridization program, were selected from a clone archive located in south-western Finland. Also, three hybrid aspen (*Populus tremula x P. tremuloides*) clones were selected from the Finnish tree breeding program.

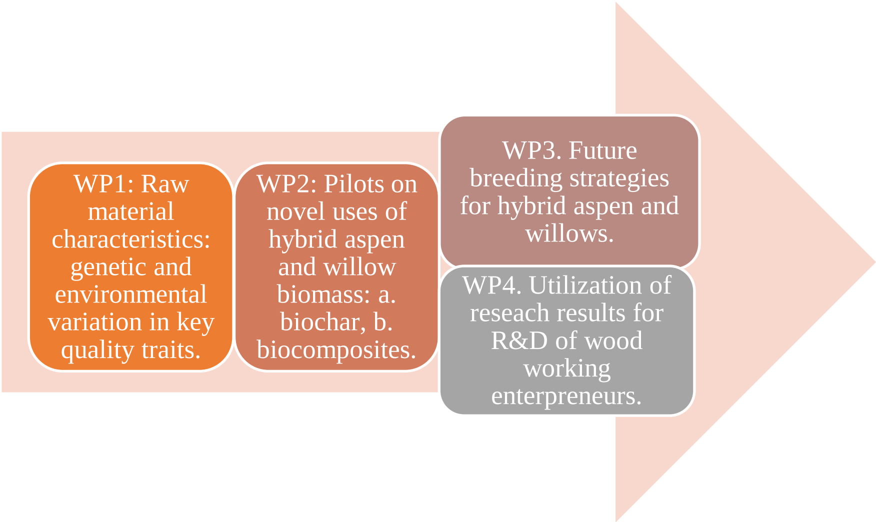

Figure 1: Schematic presentation of the demonstration project "AspenWill": bringing together knowledge of the whole value-chain from tree breeding to end-use processing and functionalities of novel end-products of willow and aspen.

In the first phase of the project, the between- and within-species clonal variation in key quality traits of wood has been determined. Fibre properties (e.g., length, width, coarseness, and length distributions) were measured from macerated specimens by using Valmet Fibre Image Analyzer (FS5). For the analysis of wood porosity (being important indicator for porosity and thus water retention potential of biochar), other specimens were over-dried and analysed in 3D by using X-ray microtomography at 1-µm -resolution.
In the next phases of the project, we will quantify how the key raw material properties affect the end-product properties and functionalities. Luke´s bench scale pyrolysis facility will be used to produce designed biochar, followed by its structural and chemical characterization (HYVÄLUOMA ET AL. 2017). Biocomposites will be produced from willow and aspen by using an extrusion technique, and the mechanical and physical properties of biocomposites will be determined. With this approach, genetic properties of willow and aspen wood can now be linked on structural and chemical qualities of designed biochar and biocomposites for the first time in biochar and biocomposite research history.
Preliminary results will be presented on the clonal variation in fibre properties, 3D pore space structures of willow wood, as well as of the growth and coppicing vigour of the willow clones.

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Demonstration of the database macroHOLZdata computer-aided identification and description of trade timbers

Gerald Koch[1], Immo Heinz[1], Hans-Georg Richter[1]

[1] Thünen Institute of Wood Research, Leuschnerstr. 91, 21031 Hamburg, Germany

gerald.koch@thuenen.de

Keywords: database macroHOLZdata, wood identification, wood properties

ABSTRACT

The knowledge about recognition and utilization of commercial timbers is of prime importance to timber trade and wood industry for the assessment of product quality. Furthermore, wood identification is important in enforcing the control of illegal logging according to the European Timber Regulation (EUTR) and CITES policies (KOCH ET AL. 2008).

A valuable support for computer-aided wood identification based on macroscopic features is available by the database **macroHOLZdata** developed in the DELTA-INTKEY-System. The database enables the user to identify trade timbers by means of macroscopic wood structural features (RICHTER ET AL. 2003). Macroscopic structural features are those which can be observed with the unaided eye or with the help of a magnifying lens (about 6x to 12x). In addition to computer-aided identification this digital learning tool allows access to a data pool with timber specific information on properties, utilization, and other relevant characteristics of the timbers integrated in the database, i.e., data on biological, physical and mechanical properties, wood machining, wood processing, and appropriate end uses.

Particular care has been taken to provide high quality illustrations with the database. Features pertaining to the character list and the timbers comprising the database are illustrated (Fig. 1). These illustrations are produced at a magnification commensurate with macroscopic observation enabling the user to make direct comparisons with certain character expressions or between an unknown timber to be identified and a known timber in the database (Fig. 2). Furthermore, nearly all characters used for description and identification are accompanied by explanatory notes with definitions, examples, procedures, etc.

The described features and information of the database will be practically introduced / demonstrated during the presentation.

The database m**acroHOLZdata** caters to all primary and secondary educational facilities with a curriculum including coursework in forestry and forest products and related subjects. It may also constitute a very useful tool for professionals in forestry, wood industry and the wood products market, architecture, engineering, etc.

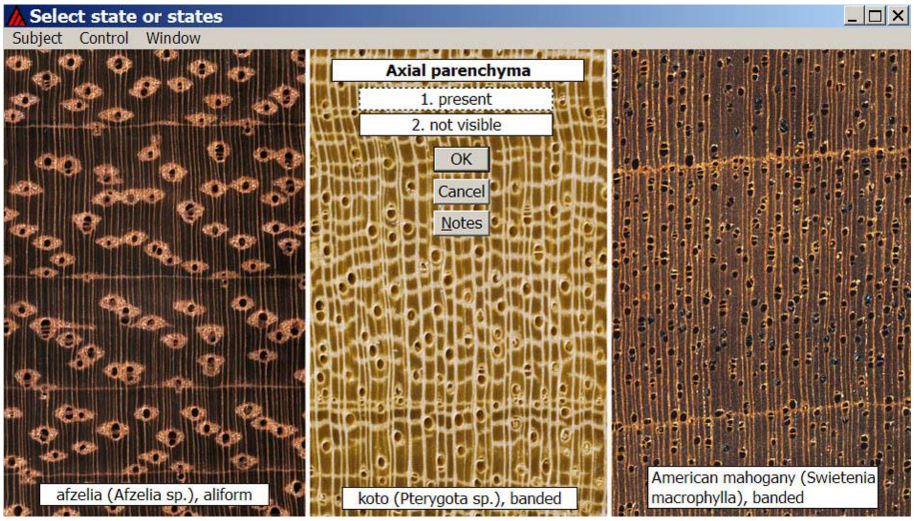

Figure 1: Arrangement of axial parenchyma representing an important feature for macroscopic wood identification

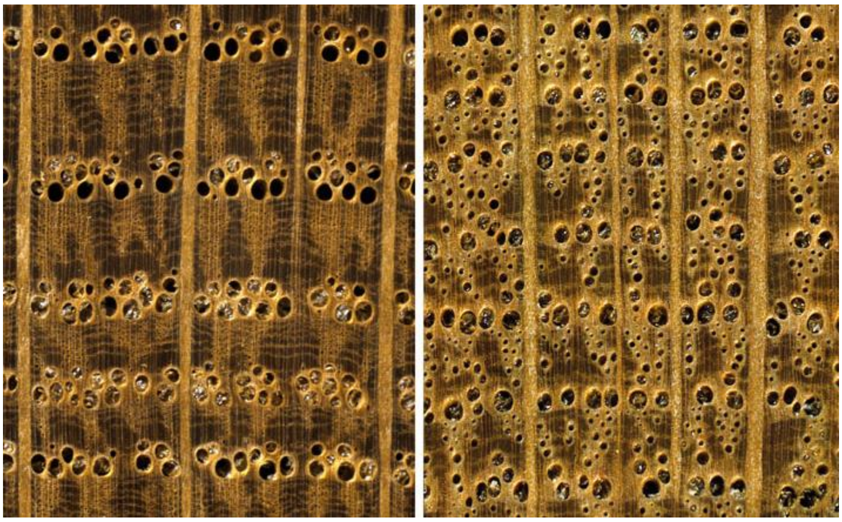

Figure 2: Differentiation between White oak (left) and Red oak (right) on the macroscopic level

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Moisture-dependent elastic characteristics of cherry wood by means of ultrsound and mechanical tests

Erik Valine Bachtiar[1], Peter Niemz[2]

[1] Technical University Dresden, Institut für Statik und Dynamik der Flächentragwerke, von Mises-Bau (VMB), room 101A Georg-Schumann-Str. 7, Germany, berik@ethz.ch

[2] Peter Niemz, Bern University of Applied Sciences, Institute for Wood Technology and materials, Solothurnstrasse 102, CH 2500 Biel 6, peter.niemz@bfh.ch

Keywords: walnut, cherry, mechanical properties, orthotropy, ultrasound

ABSTRACT

In wood science, ultrasonic testing is one of the preferred non-destructive testing methods for estimating the anisotropic elastic properties of wood materials. This method is known to be reliable for estimating the elastic stiffness in the principal anisotropy axes (longitudinal, radial and tangential) and the shear stiffness on the material planes of wood. However, the applicability of this method to estimate other mechanical properties, for instance the Poisson's ratios, still remains uncertain. On the other hand, despite their destructive nature, mechanical tests allow direct measurement of all elastic properties including the Poisson's ratios, hence they are used as a calibration reference for ultrasonic measurements of different wood species.In this study, two types of hardwood Walnut (Juglans regia L.) and Cherry (Prunus avium L.) are tested using both ultrasonic and mechanical testing methods. These species frequently appear in cultural heritage objects in museums (e.g. musical instruments, furniture). However, their elastic properties have only been scarcely investigated. Three data evaluation techniques which differ in the way to incorporate the Poisson's ratios (full-stiffness-inversion, simplified uncorrected, and simplified corrected) are used to estimate the elastic moduli from the ultrasonic results.
The full-stiffness-inversion method requires four specimen types and give the best estimation for the elastic moduli (5% deviation). The simplified uncorrected method requires only once specimen type, but leads to an overestimation of elastic moduli (44% for L Young's modulus). The corrected method based on the Poisson ratios obtained from mechanical tests only partially reduces the overestimation to 27% for L Young's modulus. From the present results it become clear that the chosen data evaluation method influence the accuracy of the calculated elastic moduli.

Table 1: Walnut (Juglans regia L.) measurements and data evaluation results

Walnut		Mechanical		Ultrasound			
		Compression	Literature[a]	Full stiffness inversion (Tab.1)	Simplified, uncorrected (Eq.3)	Simplified, corrected (Compression's Poisson's ratio) (Eq.4)	Simplified, corrected (Literature's Poisson's ratio) (Eq.4) [a]
		u = 9.2%	u =11 %	u = 9.2%	u = 9.2%	u = 9.2%	u = 9.2%
		ρ = 693 kg/m³	ρ= 590 kg/m³	ρ = 647 kg/m³	ρ = 647 kg/m³	ρ = 647 kg/m³	ρ = 647 kg/m³
E_L	(MPa)	10721	11416	11190	16189	15745	14578
E_R	(MPa)	1149	1214	1377	2910	2403	1967
E_T	(MPa)	1083	641	682	1565	1298	1061
$G_{RT}=G_{TR}$	(MPa)	-	234	264	264	264	264
$G_{TL}=G_{LT}$	(MPa)	-	714	995	995	995	995
$G_{LR}=G_{RL}$	(MPa)	-	980	1389	1389	1389	1389
ν_{RL}	(-)	0.035	0.052	0.055	0	0.035	0.052
ν_{LR}	(-)	0.290	0.490	0.448	0	0.290	0.490
ν_{TL}	(-)	0.032	0.036	0.079	0	0.032	0.036
ν_{LT}	(-)	0.193	0.636	1.298	0	0.193	0.636
ν_{TR}	(-)	0.297	0.375	0.437	0	0.297	0.375
ν_{RT}	(-)	0.524	0.710	0.883	0	0.524	0.710
Correction factors			k_L (-)	1.4468	1	1.0282	1.1105
			k_R (-)	2.1128	1	1.2108	1.4791
			k_T (-)	2.2962	1	1.2059	1.4749

[a] results based on Keylwerth 1951

Table 2: Cherry (Prunus avium L.) measurements and data evaluation results

Walnut		Mechanical		Ultrasound			
		Compression	Literature[a]	Full stiffness inversion (Tab.1)	Simplified, uncorrected (Eq.3)	Simplified, corrected (Compression's Poisson's ratio) (Eq.4)	Simplified, corrected (Literature's Poisson's ratio) (Eq.4) [a]
		u = 9.2%	u =11 %	u = 9.2%	u = 9.2%	u = 9.2%	u = 9.2%
		ρ = 693 kg/m³	ρ= 590 kg/m³	ρ = 647 kg/m³	ρ = 647 kg/m³	ρ = 647 kg/m³	ρ = 647 kg/m³
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$G_{RT}=G_{TR}$	(MPa)	-	234	264	264	264	264
$G_{TL}=G_{LT}$	(MPa)	-	714	995	995	995	995
$G_{LR}=G_{RL}$	(MPa)	-	980	1389	1389	1389	1389
ν_{RL}	(-)	0.035	0.052	0.055	0	0.035	0.052
ν_{LR}	(-)	0.290	0.490	0.448	0	0.290	0.490
ν_{TL}	(-)	0.032	0.036	0.079	0	0.032	0.036
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			k_T (-)	2.2962	1	1.2059	1.4749

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Drying Characteristics of Sapwood, Discoloured Wood and Infected Wood of Box Elder (*Acer negundo* L)

Denis Plavčak[1], Željko Gorišek[1], Aleš Straže[1], Maks Merela[1]

[1]University of Ljubljana biotechnical Faculty, Department for Wood Science and Technology

zeljko.gorisek@bf.uni-lj.si

Keywords: moisture content, collapse, permeability, diffusivity, *Acer negundo*

ABSTRACT

Box elder (*Acer negundo* L) is among the most prevalent maple trees in the natural environment of North America. In Europe, we find it from the 17. Century. Originally planting in parks and urban environments, its growth eventually become uncontrolled and today, we are already attributing it as invasive species. The young box elder grows relatively quickly, but it has limited lifetime (to app. 75 years). Therefore, a large proportion of juvenile wood reduces its value and usefulness. The wood is characterized as light, with poor mechanical properties and in the industry it is not appreciated very much. Outstanding texture of rare and beautiful burls, several times containing distinctive pinky-red coloured areas, offers a big challenge to produce unique decorative products.

The formation of discoloured (red stain) wood is the response of living tree to external injuries accompanied with compartmentalization processes (MORSE & BLANCHETTE, 2002). A huge appearing of tylosis and after than infection with microorganisms make discoloured wood very problematic to dry. Often heavily damaged box elder trees with distinct appearance represent great potential for making high-value products. Preparation of quality dried wood requires a good knowledge of moisture distribution and drying characteristics of normal sapwood, discoloured wood and infected wood. All three categories of wood can be distinguished visually or with colourimetry (sapwood 75.4, 8.1 and 8.2, discoloured wood 48.6, 17.7 and 7.6, infected wood 51.8, 9.3 and 7.8 for L, a and b coordinates respectively). In sapwood as well as in red stained wood we did not find fungus or other microbial infection whereas infected areas of wood were intertwined by hypha (examined by SEM Quanta 250).

The basic density (absolutely dry mass/green volume) of box elder wood is low (474 kg/m^3, st. dev. 27.1) with insignificant difference between juvenile and adult wood. Much more interesting is distribution of moisture content with the highest value in discoloured areas (Fig. 1).

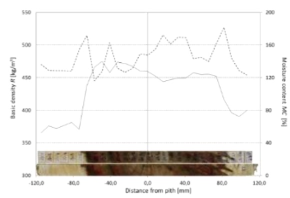

Figure 1: - Typical radial distribution of moisture content MC (---) and basic density R (- - -) in fresh cut box elder stem.

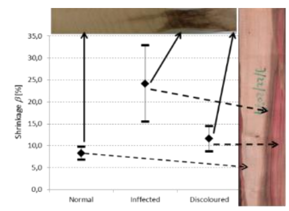

Figure 2: -Shrinkage of normal, infected and discoloured box elder wood (cross section – picture above; radial plane – picture on right).

The high regular shrinkage of box wood is in the discoloured region often accompanied with collapsing tissue. Extremely extended collapse occurred in infected tissue while slightly smaller happened in discoloured wood (Fig. 2).

Collapse occurs if the capillary tension exceeds the compression strength of wood. Capillary tension is heavily dependent on wood permeability. The comparison of gas permeability (GORIŠEK & STRAŽE, 2009) showed that the infected wood has the lowest conductivity which means 3.5 times less than sapwood and 1.3 times less than discoloured wood (Tab. 1).

Table 1: - Coefficients of permeability for sapwood, infected wood and discoloured wood of box elder with basic statistics.

	Sapwood	Infected wood	Discoloured wood
		k_g [m^3/(m Pa s)]	
Average	**1,59E-07**	**4,53E-08**	**5,53E-08**
St. deviation	7,24E-08	1,49E-08	1,41E-08
c.v. [%]	45,5	32,9	25,5
Min.	7,58E-08	2,49E-08	3,89E-08
Max.	3,04E-07	7,50E-08	8,58E-08

The difference of diffusivity was insignificant between all tree examined wood categories therefore we represent only average values of surface emission coefficient and diffusion coefficient at temperature 20 °C and 40 °C (method after SIAU, 1995).

Table 2: - Surface emission coefficient and diffusion coefficient of box elder at two temperatures.

Temperature	Surface emission coefficient	Diffusion coefficient
	[m/s]	[m^2/s]
T = 20 °C	1,20E-08	1,27E-09
T = 40 °C	1,87E-08	5,21E-10

The stripes of red stain in box elder wood are abiotic origin as reaction on external injuries with aeration and desiccation of effected tissue. At the same time the tissue is also biotical infected. Under favourable condition micro-organisms begin to grow with which they damage the cell wall and consequently they reduce the strength of wood. Lower permeability and a little greater shrinkage of discoloured wood compared with sapwood coincident with greater occurrence of tylosis and collapsing tissue occurring in the first stage of drying. Combination of great number of tylosis and cell wall strength reduction are the main causes of huge collapse in infected wood. Therefore, box alder discoloured wood have to be dried with low temperature and at moderate drying gradient especially during the first stage of process.

ACKNOWLEDGEMENT

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Experimental determining of mass transfer coefficient during oak wood convective drying

Nikolay Skuratov[1]

[1] 141005 2nd Institutskaja str. 1, Mytishi, Moscow Region, Russia, Bauman Moscow State Technical University, Mytishchi branch, skuratov@mgul.ac.ru

Keywords: Wood drying, diffusion, surface moisture content, mass transfer coefficient, boundary layer theory

ABSTRACT

In the process of low-temperature drying, the movement of water from the inside to the surface of wood occurs mainly under the action of a moisture gradient. The moisture transfer in the wood has a complex character. Its intensity is determined by the diffusion coefficient which depends on many factors. These include the direction of flow, temperature, density and the moisture content of the wood.

The intensity of moisture removal from the surface layers of wood during the drying is determined by the conditions of its interaction with the surrounding air. The moisture exchange between the wood and the surrounding air is one of the factors determining the process of drying. The mass transfer coefficients, as quantitative characteristics of this phenomenon, are necessary for the analysis, computation and optimization of the processes of convective drying of the wood. The ratio of the mass transfer coefficient to the diffusion coefficient significantly influences the magnitude of the moisture gradient in the wood surface zones and as a consequence the level of drying stresses.

In most of the studies on the determination of the mass transfer coefficients at wood drying the approximate solutions of well-known diffusion equation or boundary layer theory were used [WADSO 1993, HUKKA 1999]. There is also a method for determining the mass transfer coefficients by means of the known balance equation connecting the rate of change in the average moisture content of the board and the flux density of water on its surface, where the complicated colorimetric $CoC1_2$-treated wood technique is used for determining the surface moisture content of wood [YEO ET AL. 2007].

In this paper, the balance equation was also used to determine the mass transfer coefficients but the surface moisture contents of wood were measured differently. There was used a new method for determining the surface moisture content of wood during the drying process [SKURATOV ET AL. 2016]. Its value is determined as the equilibrium moisture content in the thin boundary air layer the parameters of which are measured directly above the wood surface. The Sensirion SHT20 miniature sensor fixed in the special device was used to measure the temperature and the relative humidity of the air in the micro-volume at the surface of the wood samples.

The mass transfer coefficients were determined by the results of the drying experiments of 5x60x400 mm oak samples at the temperature of 50 ° C and 60 ° C and the relative humidity of 73% and 45%. The air velocity along the samples in the laboratory chamber measured with a hot wire anemometer was about 1.5 m/s. The ends and edges of the samples were moisture-insulated with silicone. During each experiment, the surface and the average moisture content of the samples were periodically measured. Using these data, there were calculated the mass transfer coefficients for different times of the drying processes and the values of surface moisture content. The results of determining the mass transfer coefficients are shown in Fig. 1. It turned out that the greatest influence on the mass transfer coefficient is exerted by the surface moisture content. With a decrease in the surface moisture content, a sharp increase in the mass

transfer coefficient occurs. At the same time, there was found no significant effect of temperature and relative humidity of air in the investigated range of their changes on the mass transfer coefficient.

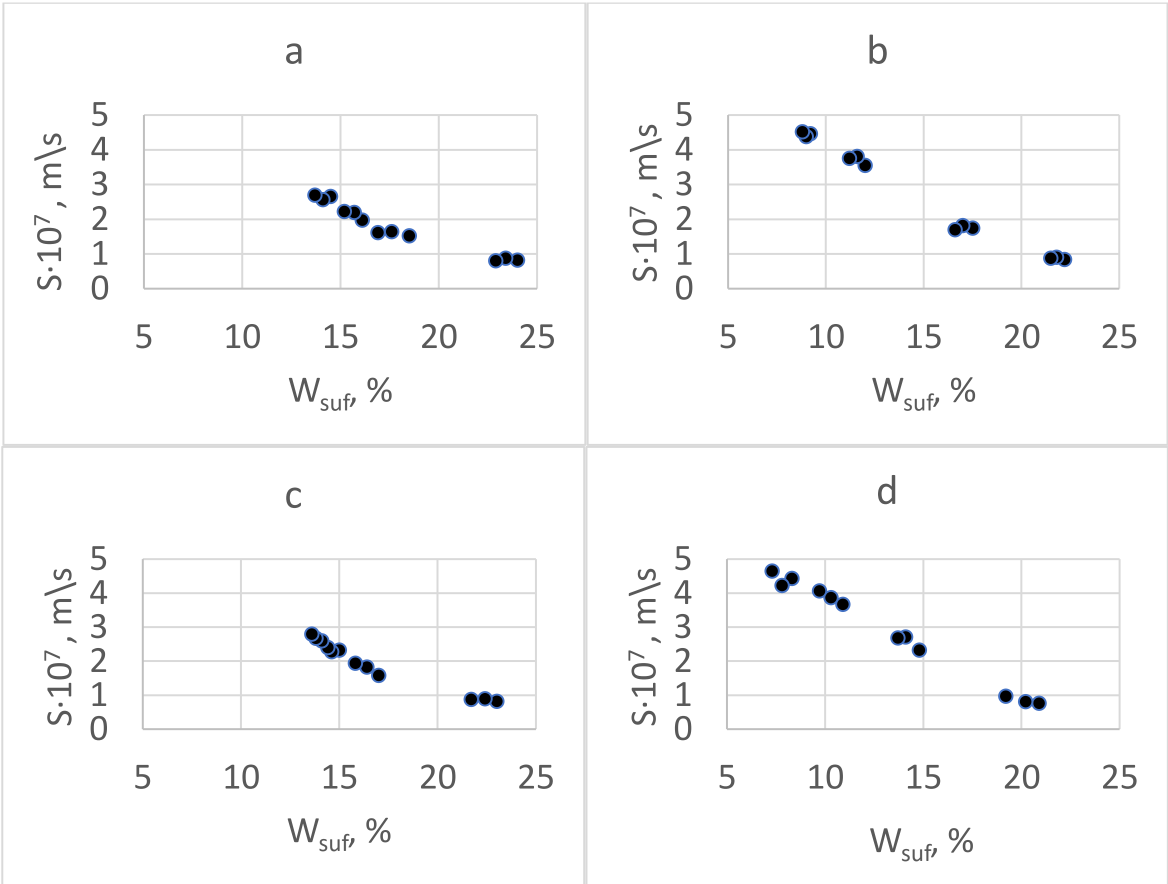

Figure 1: Effect of surface moisture content (Wsuf) on the mass transfer coefficient (S) at different values of temperature (t) and relative humidity (φ) of air (a – t=50°C, φ=73%; b – t=50°C, φ=45%; c – t=60°C, φ=73%; d – t=60°C, φ=45%)

In further studies, the range of changes of the air temperature and relative humidity is expected to be extended. Also, the effect of air velocity on the mass transfer coefficient will be determined.

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Parallel Session II.
Chemical aspects of hardwood processing

Intensification process for the conversion of Kraft-hardwood lignin into small phenolic compounds

Javier Fernández-Rodríguez[1], Fabio Hernández-Ramos[2], Xabier Erdocia[3], María González Alriols[4], Jalel Labidi[5]

Biorefinery Processes Group, Chemical and Environmental Engineering Department, University of the Basque Country, UPV/EHU, Plaza Europa, 1, 20018, Donostia-San Sebastián, Spain
[1]javier.fernandezr@ehu.eus

[2]fabio.hernandez@ehu.eus

[3]xabier.erdocia@ehu.eus

[4]maria.gonzalez@ehu.eus

[5]Jalel.labidi@ehu.eus

Keywords: hardwood, lignin, depolymerization, phenolic oil, catechol

ABSTRACT

Although lignin is produced worldwide in an amount of around 70 million tonnes, only 1-2% is intended as precursor for chemicals and materials. Fortunately, the trend is finally moving to a different scenario. For example, the company Stora Enso has been recently awarded for its lignin-base product Lineo™ as "Bio-Based Product of the Year" at the Bio-Based World News Innovation Awards 2018.

Despite this trend in the global market, the usage of lignin as chemical and/or material is only applied to not high value-added solutions. Last years, many researches have demonstrated the potential of lignin as source of phenolic monomers by cleaving it into smallest entities. Depolymerization of lignin has been widely studied by several methods to get phenolic monomers with greater potential as chemical building blocks. However, its scaling up has not been industrially implanted so far.

In this sense, hardwood lignin has been embraced as more suitable source than softwood lignin due to its higher percentage of β-O-4 linkage, which enables to obtain a greater reaction yield than using softwood lignin (PANDEY AND KIM 2011). Therefore, Iberian pulp manufacturers are considered as key players to develop this technology in Europe as its main wood source is eucalyptus, a hardwood species.

Among lignin depolymerization methods Base Catalyzed Depolymerization (BCD) has been widely used due to its simplicity and efficiency. The yield of this reaction is limited by the action of a repolymerization reaction that occurs when reactive phenolic and catechol derivative monomers undergo a polymerization reaction instead of remaining as monomeric products, generating residual lignin and coke as undesirable products (ROBERTS ET AL. 2011). TOLEDANO ET AL. (2014) demonstrated that phenolic oil could be notably increased adding phenol as capping agent to an alkali medium in order to depolymerize lignin. On the other hand, the oxidative depolymerization of lignin could be considered as other option to depolymerize lignin from its initial structure to small molecules. ARAUJO ET AL. (2010) used this approach to obtain vanillin from lignin, using oxygen in alkali solution.

In this work, Kraft black liquor obtained from hardwood lignin, was directly depolymerizated without previous isolation of lignin as it is done mostly in similar works. In this sense, the stage of lignin precipitation could be bypassed, reducing the costs by the intensification of the process flowsheet. As Kraft black liquor presents an alkali medium, BCD depolymerization of lignin is carried out to obtain small phenolic compounds. Furthermore, the influence of different

chemical agents is studied in order to maximize phenolic oil production as well as to reduce residual lignin and coke production, which are the undesirable products of the reaction.
Three main products were obtained for each reaction: phenolic oil; residual lignin, which is produced as a result of the undesirable repolymerization reaction that occurs in parallel; and char, a recalcitrant product with a high condensed structure. Reaction yields for each reaction studied in this work are summarized in Table 1.

Table 1: Yield of obtained products after Kraft black liquor treatment

Reaction media	Oil (% w/w)	Residual lignin (% w/w)	Char (% w/w)
Kraft liquor (blank)	30.09±1.03	39.43±1.57	24.52±0.98
Kraft liquor (phenol)	31.91±0.88	44.87±1.22	15.72±0.69
Kraft liquor (H_2O_2)	18.24±1.10	37.25±1.46	18.04±0.98

High yield of phenolic oil was recovered after treatment of the Kraft liquor in blank reaction (~30 %). However, high amount of undesirable products (residual lignin and coke) was also obtained (~65 % between both). The addition of phenol as capping agent reduced coke formation (almost to the half); and monomer phenolic compounds in oil were increased four times. The use of hydrogen peroxide reduces the phenolic oil yield (lower than 20 %). Catechol derivatives were the most plentiful products in the phenolic oil (92.44 % of total phenolic monomers) and a decreased of coke formation was similar to that in phenol.

As summary, it can be established that the intensification of the lignin depolymerization can be accomplished with high yields of phenolic oil production by avoiding the isolation of lignin and its further solubilization.

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Polyols from lignin and sawdust of oak wood

Silvia Helena Fuentes da Silva[1], Itziar Egües[2], Jalel Labidi[3]

[1] Chemical and Environmental Engineering Department, University of the Basque Country, Plaza Europa 1, 20018, Donostia/San Sebastián, Spain, email: silviahfuente@hotmail.com

[2] Chemical and Environmental Engineering Department, University of the Basque Country, Plaza Europa 1, 20018, Donostia/San Sebastián, Spain, email: itziar.egues@ehu.eus

[3] Chemical and Environmental Engineering Department, University of the Basque Country, Plaza Europa 1, 20018, Donostia/San Sebastián, Spain, email: jalel.labidi@ehu.eus

Keywords: Polyol, liquefaction, renewable source, oak hardwood, Kraft lignin, sawdust

ABSTRACT

The liquefaction process has been widely used in the conversion of lignocellulosic biomass into polyol (LEE AND LEE 2015, JO ET AL. 2015). This technique allows the conversion of lignocellulosic materials into dark liquid rich in active sites that can be used directly in the formulations of phenolic and polyurethane resins.

In this work, soda lignin extracted from oak hardwood and its sawdust were liquefied with polyethylene glycol (PEG) and glycerol (G) as solvent and without catalyst. The liquefaction reaction was carried out using PEG and G in a weight ratio of 80:20 under reflux. The mixture of solvents was charged into a glass flask and was stirred and heated. When the reaction temperature was reached, the raw material (15 wt% respect to the solvents) was added to the flask. After 1 h, the flask was immediately cooled in a water-ice bath. The polyol was filtered and washed with acetone under vacuum. Solid fraction was dried and oven-dried at 105 ºC for 24 h and weighted to determine the reaction yield. Acetone was removed by rotary evaporator under reduced pressure at 49 ºC.

This study aimed to evaluate the influence of two different renewable sources derived from oak hardwood (sawdust and lignin), on the yield and properties of obtained polyols (acid number, hydroxyl number, viscosity and pH). Molecular distribution and structural changes of polyols were also analysed.

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Eucalyptus lignins as natural additive for healthcare

Oihana Gordobil[1], René Herrera[1], Marwa Yahyaoui[2], Jalel Labidi[1]

[1] Chemical and Environmental Engineering Department, University of the Basque Country, Plaza Europa, 1, 20018, Donostia-San Sebastián, Spain

[2] Laboratory of materials and molecules Application, University of Tunisia El Manar, Farhat Hached University Campus PB 94 - Rommana 1068, Tunis, Tunisia

Keywords: organosolv lignin, industrial kraft lignin, sun blocker, antioxidant

ABSTRACT

The last trends pursue the replacement of some synthetic products by the utilization of renewable and sustainable compounds. For that reason, lignin, the only high-molecular-weight natural polymer with an aromatic structure in nature, has become one of the most interesting biological compounds as an alternative to fossil resources(Cui et al., 2014; Jääskeläinen et al., 2017). In addition, its high availability, low price and properties, make interesting the development of new and valuable uses for lignin, thus improving the economic and environmental aspects of the biomass conversion. The chemical structure of lignin is highly influenced by the extraction process and origin of the lignocellulosic material. This work offers a comparative study of extracted organosolv lignin and industrial Kraft lignin from *Eucalyptus*. The Kraft black liquor is produced in large quantities as a by-product annually. It is estimated that there are around 70 million tons of lignin from the kraft pulp manufacturing process worldwide(Jääskeläinen et al., 2017). Moreover, it has been estimated that lignocellulosic bioethanol production will produce around 62 million tons of lignin as waste for the year 2022(Jääskeläinen et al., 2017; Liu et al., 2018). Although both type of lignins come from *Eucalyptus*, there are several differences between them such as purity, sulfur content as well as chemical composition and structure, and it have an important effect on their final properties. The main objective of this study was to evaluate selective functional properties of kraft and organosolv lignin samples in order to explore their potential use for different fields. For this purpose, antioxidant potential and their potential as natural additive for sunscreen was evaluated. Fig. 1 shows the inhibitory effect of lignin samples toghether with used positive controls (BHT and Trolox) As can be observed, OE presented higher antioxidant power than BHT control but lower than Trolox. However, KE presented lower antioxidant capacity than BHT and Trolox. The antioxidant activity of lignin is not only related to the phenolic hydroxyls content(Lu et al., 2012). It is also influenced by substituents like methoxyl(Pan et al., 2006) or carbonyl groups(Kaur and Uppal, 2015). The stronger DPPH-scavenging capacity of OE was mainly due to the highest methoxyl content and lowest carboxylic acid content. Moreover, the lower radical scavenging activity of KE could be partly attributed to the presence of very high content of carboxylic acids and its low phenolic content together with its low purity. Moreover, in order to study the natural sunscreen properties of Eucalyptus lignins, lignin samples were blended with a standard commercial cream (Cream-D) at 1% and 5% and their sunscreen properties were analyzed by UV. To carry out the test, the commercial cream (Cream-D) was taken as negative control and the cream with SFP 50 was taken as positive control. The Results showed that pure cream (Cream-D) had no absorbance; however, cream with SPF 50 (Cream-SPF50) exhibited a transmittance of 0% demonstrating its high SPF. In addition, as shoes Fig. 2, with the addition of 1% of lignin the transmittance was reduced between 40-50% the transmittance and with 5% of lignin, it was reduced 70-90%. These results suggest the potential of lignins as sunscreen product

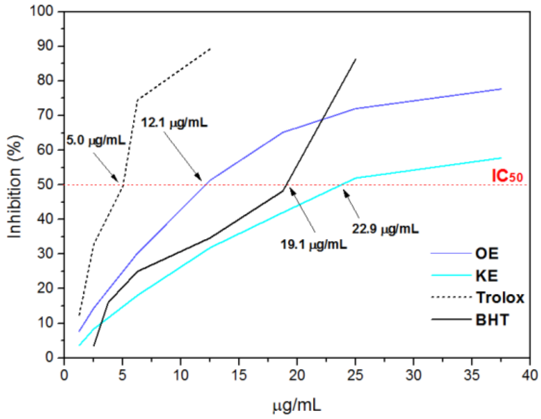

Figure 1: Antioxidant activity of lignin against DPPH and their comparison with BHT and Trolox used as positive controls.

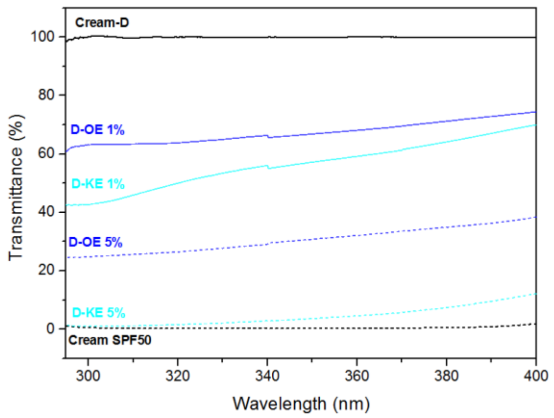

Figure 2: UV transmittance of creams containing 1% and 5% of organosolv and Kraft lignins.

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Characterisation of extractives from black alder

Kerstin Wagner[1], Stefan Willför[2], Herman Huber[1], Alexander Petutschnigg[1,3], Thomas Schnabel[1]

[1] Salzburg University of Applied Sciences, Forest Products Technology & Timber Constructions, Markt 136a, 5431 Kuchl, AUSTRIA, kerstin.wagner@fh-salzburg.ac.at

[2] Åbo Akademi University, Johan Gadolin Process Chemistry Centre, Laboratory of Wood and Paper, Chemistry, Porthansgatan 3, 20500 Turku/Åbo, Finland

[3] BOKU University of Natural Resources and Life Sciences, Konrad Lorenzstraße 24, 3430 Tulln, AUSTRIA

Keywords: Black alder, Extractives, Gas Chromatography - Mass Spectroscopy

ABSTRACT

The black alder *[Alnus glutinosa (L) Gaertn.]* is a fast growing and widely spread tree species across Europe, which covers less than 1% of the forest area in most European countries (Claessens et al. 2010). Due to the global climate change and the increasing global concern about the impact of fossil fuels, alternatives from bio based raw-materials like short rotation woody crops have come into focus of research in recent years (Ghaley and Porter 2014). Furthermore, there is a re-evaluation of natural active compounds and plant sources in the pharmaceutical industry, because recent research revealed that the compounds of the black alder has antioxidant and anxiolitic properties (Abedini et al. 2016, Felföldi-Gàva et al. 2012).

The aim of this study was to characterise the extractives from black alder trees. The material was collected in the alluvial forests in the province Salzburg in Austria and was grounded fresh. Afterward the material was separated into bark and biomass chips. The biomass chips included bark, wood, leaves and fruits, which were air-dried. To produce extractives, the following screening method was applied for the extraction with different solvents (e.g. methanol and water): 1 g of wood powder was pipetted with 10 mL of a solvent and was extracted for 24 hours. After this the solution was filtered and then analyzed. In addition to that, the following extraction method was applied, accelerated solvent extraction (ASE) with different solvents, e.g. acetone and n-hexane. Furthermore, the compounds in the liquid were characterised using gas chromatography–mass spectrometry (GS-MS) and UV-Vis spectrophotometry.

The main compounds in the black alder extractives were different sterols (fig. 1) and monosaccharides. In addition to that, lupeol was also detected except in the acetone extractives. Usually lupeol occurs in the bark of black alder, in leaves and fruit waxes (Felföldi-Gàva et al. 2012). Furthermore, malic acid was found excluding in n-hexane extractives. The highest amount of malic acid was detected in the water extraction of the black alder from biomass chips. In addition to that, traces from 0.019 till 0.220 mg g^{-1} catechin were discovered in the samples extracted with acetone and methanol. In the methanol bark extractive sample the lignan lariciresinol was also detected.

The results of this study show that black alder bark and chips for biomass contain important compounds which have antioxidant and anxiolytic properties. Even if they occur in low concentration in the plan material, they are important natural compounds for the pharmaceutical industry and have high potentials for the biocosmetic industry (Abedini et al. 2016, Felföldi-Gàva et al. 2012).

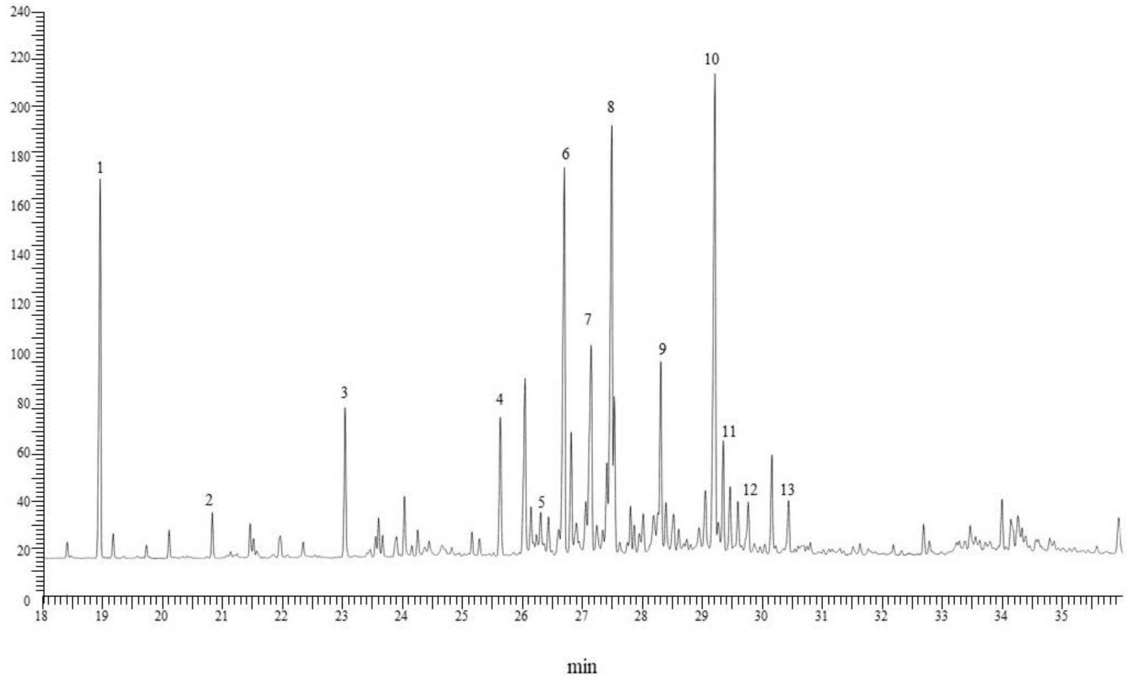

***Figure 1:** GC chromatogram of black alder [Alnus glutinosa (L) Gaertn.] chips extracted with accelerated solvent extraction. Peak assignments: 1) internal standard; 2) N-DOCOSANE; 3) N-NONACOSANE; 4) alcohol 28; 5) campesterol; 6) lupen-3-one; 7) sitosterol; 8) amyrin; 9) hydroxydammarenone; 10) internal standard; 11) betulinic acid; 12) lupine-3; 13) eicosanyl-coumarate*

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In-situ Micro and Nano mechanical investigations of compressed beech wood using Scanning Electron Microscope with Focused Ion Beam

Petr Klímek[1], Darius Tytko[2], Marek Dosbaba[3], Radim Rousek[4]

[1] Tescan Orsay Holding a.s., Global Application department – Material Science, Libusina trida 863/21, 623 00 Brno, Czech Republic, email: petr.klimek@tescan.com

[2] Tescan GmbH, Application department – Material Science, Zum Lonnenhohl 46, 44319 Dortmund, Germany

[3]Tescan Orsay Holding a.s., Global Application department – Material Science, Libusina trida 863/21, 623 00 Brno, Czech Republic,

[4] Mendel University in Brno, Department of Wood Science, Zemedelska 1, 613 00 Brno, Czech Republic

Keywords: Beech, Scanning Electron Microscopy, Focused Ion Beam, Nano indentation, Micro pillar preparation

ABSTRACT

Wood is a hierarchically organized material with many cellular and intercellular elements. These elements are, in general, co-responsible for mechanical behaviour of the wood. While structural mechanical properties important for engineering are tested and testing is subjected to many standards, the micromechanical behaviour is evaluated with various non-standardized techniques. Frequent technique for cell-wall mechanical properties evaluation is the nano indentation. Introduced in “wood science” by Wimmer et al., (1997) was followed by other investigations of different natural materials later (STOECKEL ET AL. 2013; GINDL & SCHO 2004; ARNOULD ET AL. 2017). Although, nano indentation was not found the most suitable method for determination of absolute values of wooden cell walls mechanical properties, it remains to be called as the *“appropriate method for comparative studies at the cell wall scale”*(JÄGER ET AL., 2011). Aside of the fact that nano-indentation is not feasible for determination of absolute values of cell wall mechanical properties, we see also additional limits for the “stand alone” Nano indentation. For wood the limits of basic nano-indentation systems can be the lack of resolution when navigating on the sample, possibility to evaluate single spots only and absence of additional information about cell-wall composition (Layers, fibril angles, chemistry etc.). This motivated us to design study which is going to employ a single scientific instrument and provide complex investigation about micromechanics, chemistry and structure of compressed beech wood.
In our research we have designed a study which employs Scanning Electron Microscope with Ga^+ focused ion beam (TESCAN a.s., Brno, Czech republic) equipped with confocal Raman microscope and in-situ nano indentation table. We have used such a system to evaluate the effect of steam treatment and compression on the mechanical properties of wooden cell wall from the study of Rousek et al., (2015). Regarding the aforementioned challenges with the micro and Nano mechanical investigation of wood, we have made following measures io research design. Mainly, nano indentation mapping (thousands of point measurements) will be done over the specific area correlatively with the SEM and RAMAN observation. This allows direct correlation of the mechanical properties with the results of RAMAN chemical mapping and SEM imaging as all the results can be done at the same regions of interest without sample removal from the instrument. The result will contain three maps: (1) topographical and visual

image of the area from SEM, (2) Raman chemical map and (3) Modulus map from nano indenter.

The subsequent part of our study is the introduction of the first results from micro pillar preparation for testing of wood cell-wall in compression (Figure 1.). In this case site specific micro pillar (radius 5µm, height 10 µm) is prepared from a cell wall with focused ion beam. Then flat type of a tip in Nano indenter is used and compressive force on the pillar is applied. The Nano pillar can be prepared from whole cell wall as well as just from the region of interest (middle lamella or S2 layer, previously specified with RAMAN).

All aforementioned techniques integrated into depicted workflow may provide new methods how to evaluate mechanical behaviour of the wood on microscale in general. Aside of that, our case study may provide an answer to a question: How the steam treatment or compression of the beech wood affects the mechanical properties of the wooden cell wall?

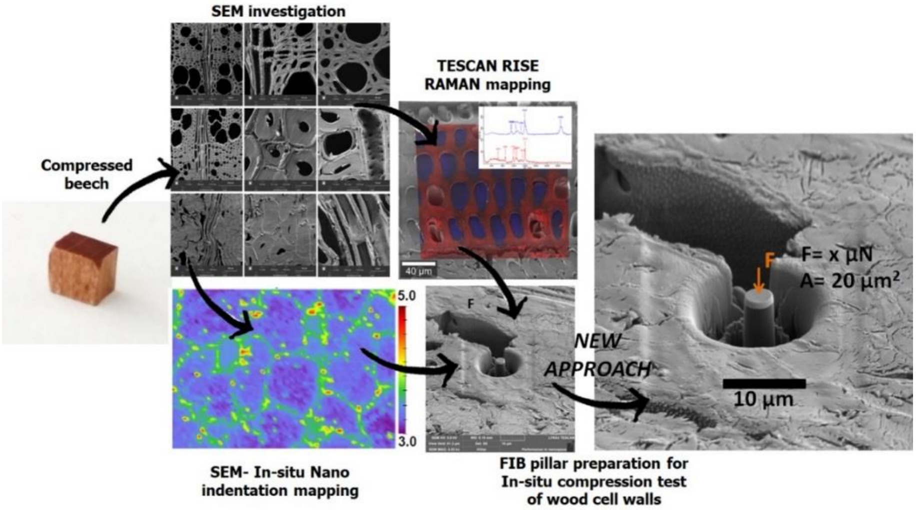

Figure 1. Workflow of the Micro and Nano mechanical investigation from wood specimens

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Chemical modification of *Eucaliptus niteens* using fatty acids

René Herrera[1a], Oihana Gordobil[1b], Pedro L. de Hoyos-Martinez[1c,2], Jalel Labidi[1d], Rodrigo Llano-Ponte[1e]

[1] Chemical and Environmental Engineering Department. University of the Basque Country UPV/EHU. Plaza Europa, 1, 20018. San Sebastian, Spain

[a] renealexander.herrera@ehu.eus; [b] oihana.gordobil@ehu.eus; [c] pedroluis.dehoyos@ehu.eus;

[d] jalel.labidi@ehu.eus; [e] rodrigo.llano-ponte@ehu-eus

[2] University of Pau and Pays de l'Adour, IUT des Pays de l'Adour, 371 Rue de Ruisseau, 40004 Mont de Marsan, France

Keywords: wood modification, esterification process, hydrophobicity, Eucalyptus wood

ABSTRACT

The technical properties of wood depend on the deterioration of its principal cell wall components. Wood is mainly composed by cellulose, hemicelluloses and lignin, which give it a hydrophilic character showing a great affinity for water. The environmental factors (biotic and abiotic) cause instability to the wood matrix and after time the collapse. Therefore, a number of wood modification techniques have been developed during the last decades in order to ensure its long-term durability and focus the wood products on specific applications. Acid chlorides or anhydrides containing long hydrophobic chains that can provide a water-repellent effect, receiving the scientific attention with reports of improvements of a number of wood properties. For this study, samples of the hardwood specie *Eucaliptus niteens* were used (10 x 10 x 40 mm); firstly, isolating the extractives from wood (toluene: ethanol (2:1) (v/v) extraction). Successively, wood samples were oven-dried at 103±2 ºC for 24 h, and kept under vacuum atmosphere before esterification in order to facilitate the modification. The modification process took place using two different reagents: hexanoyl chloride (C6) and steaoryl chloride (C18) at different concentrations (0.1M and 1M); Pyridine (10%) was used as a catalyst. The reaction was conducted for 3h at 100ºC for hexanoyl and at 80ºC for steaoryl chloride. When the process was completed, modified wood was mixed with dietylether and washed in a Soxhlet with ethanol for 3h. After modification, some properties were measured (WPG, density, RH, surface wettability) in order to evaluate and compare the effect of the different modification parameters. The principal results are summarized in Table 1 and Figure 1. It can be appreciated an increment in the WPG and density, regarding the concentration of the products (fatty acids). In addition, a slight reduction of the relative humidity after treatment was observed.

Table 1: Results of changes in properties

Sample	Concentration [M]	WPG [%]	Density[kg/m^3]	RH[%]
control	-	-	560	9.8
C6	0.1	2.37	522	7.15
	1	6.03	543	6.71
C18	0.1	1.48	560	6.83
	1	2.16	588	6.79

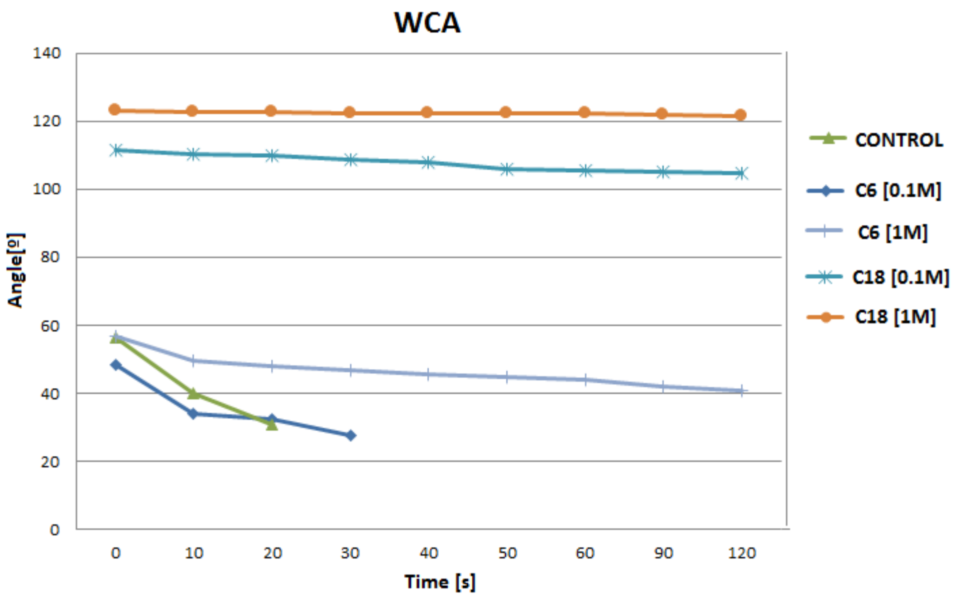

Figure 1: Water Contact Angle of samples

The dynamic contact angle (WCA) presented high values when was applied the product with long chain (C18) at high or low concentrations (0.1M or 1 M). However, the WCA in the samples with fatty acids of short chain (C6) showed values similar to control samples (Eucalyptus). These preliminary tests show interesting results in the measured properties, especially when the wood was treated with steaoryl chloride or at high concentration of hexanoyl chloride.

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Monitoring of time dependent ammonia emissions in smoked oak using FTIR spectroscopy

Elfriede Hogger[1], Klaus Bauer[2], Eva Höllbacher[1], Notburga Gierlinger[4], Johannes Konnerth[3], Hendrikus W. G. van Herwijnen[1]

[1] Wood K plus – Competence Center of Wood Composites and Wood Chemistry, Altenberger Straße 69, 4040 Linz, Austria, WMT, e.hogger@kplus-wood.at

[2] Scheucher Holzindustrie GmbH, Zehensdorf 100, 8092 Mettersdorf am Straßbach, Austria

[3] Institute of Wood Technology and Renewable Materials, University of Natural Resources and Applied Life Science, Gregor-Mendel-Straße 33, 1180 Wien, Austria

[3] Institute for Biophysics, University of Natural Resources and Life Sciences, Muthgasse 10, 1190 Wien, Austria

Keywords: Oak, Ammonia, FTIR, PLSR, µCTE

ABSTRACT

The continuing preference for dark colours in parquet and furniture leads to a necessity in the modification of domestic wood species (Aehlig et al., (2011, Weigl et al., (2009)). Such dark colours are achieved by the traditional gaseous treatment of oak with ammonia (Miklečić et al., (2012)). Aside from the advantage of the changed colour, the remaining ammonia in the wood can lead to bonding failures with resins, odour nuisance and hence to reclamations by customers (Rousek et al., (2015)). Due to these challenges and conditions it is essential to control the ammonia content of the wood. For this purpose, there are some time-consuming, partly complex and destructive processes which lead to large material losses. Therefore, the aim of this study was to develop a fast and non-destructive method, based on FTIR spectroscopy coupled to an attenuated total reflection (ATR) – unit, to replace the previously used ones.

The emitting ammonia could be reflected in the wood using the FTIR spectra in the range between 1575 – 1535 cm^{-1}, since over time the intensity of the signals at 1558 and 1540 cm^{-1} got weaker as presented in Figure 1.

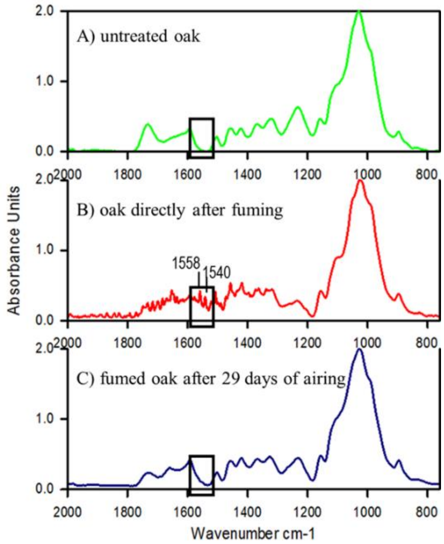

***Figure 1:** Spectral range at 2000 to 800 cm^{-1}, with focus on the affected area (1575 – 1535 cm^{-1}), where A) shows untreated oak, B) oak directly after fuming, showing the signals (1558 and 1540 cm^{-1}) related to the fuming process and C) after 29 days of airing*

The signals in this area are NH deformations, secondary amides, and amide II bands according to literature (Socrates, (2004)).
In order to verify the hypothesis of reduced ammonia emission from the monitoring of FTIR measurements, microchamber/thermal extractor – measurements (µCTE) were performed on the same samples over the same time period. The spectra were integrated in the area affected by the fuming process (1575-1535 cm^{-1}) and compared to µCTE emissions. The integrated area shows a correlation of $R^2 = 0.76$.
A multivariate statistical analysis based on partial least square regression (PLSR) was performed, to further improve the prediction accuracy. With this approach, it was possible to create promising models, with different data pre-processing methods applied (Hogger et al., (2018)). With a multiple scatter correction (MSC) of the data, a model with a high coefficient of determination ($R^2 = 0.85$), low root mean square error of cross-validation (RMSECV = 1.08 %) was created. The model can be described with only five principal components.
Within the scope of this study, a satisfactory PLS model was created, which has already been successfully integrated into production as input control for fumed oak floorboards. FTIR spectroscopy coupled to an ATR unit is a method that enables testing each individual board during production in a very short time without losing valuable raw materials. Sampling is not destructive due to further production steps. No more µCTE measurements are required once a PLS calibration has been performed.
FTIR spectroscopy has been confirmed to be a suitable, non-destructive and fast method for estimating the remaining ammonia in fumed oak floor boards.

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Parallel Session III.
Wood modification I.

Mechanical Properties of Thermally Treated Beech Wood in Compression Parallel to the Grain

Tomáš Andor[1], Rastislav Lagaňa[2]

[1] Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovakia, xandor@tuzvo.sk

[2] Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovakia, lagana@tuzvo.sk

Key words: Compressive strength, modulus of elasticity, Poisson's ratio, thermal treatment, beech.

ABSTRACT

Beech wood (*Fagus sylvatica* L.) is one of the most spread wood species in Central Europe and its processing volume will increase in the future (Anonymus 2017). Since its economic potential it is necessary to explore other improvements of its "weak" properties. One option is thermal modification, that improves large spectra of physical properties, but on the other hand negatively impact mechanical properties (Hill 2006). Generally, the compression strength is the only strength that increases after thermal treatment. Changes in physical and mechanical properties are caused by chemical changes in wood structure, that develop during the treatment. Effective utilization of thermally treated wood requires well defined changes in wood properties. This study contributed to the material properties database while determining the properties in compression parallel to the grain including Poisson's ratios μ_{RL} and μ_{TL}, and analyzed an effect of different high temperature thermal treatments on those properties.

Material and Methods

Dimensions of ideal beech wood sample were 32x32x120 mm^3 (RxTxL). Before a thermal treatment, the samples were oven dried. Three temperature levels in the oxidized atmosphere, 160°C, 180°C and 200°C, and two treatment times, 1.5 h and 3 h were used. Samples were placed in conditioning chamber after each treatment at the temperature of 20°C and relative humidity 65% until they reached equilibrium moisture content. Strength and modulus of elasticity in compression parallel to the grain were measured according to procedure of ADTM D198. Full field deformation on the surfaces were measured using Aramis 3D system. Active and passive deformations were measured from the field at the middle of a sample avoiding an edge effect of a compression test.

Results and Discussion

Compression strength apparently increased by 10% up to 54.6MPa at 180°C-3h treatment (Fig. 1). A significant increase of the strength of 1.5 h treatment was noticed at 180°C ($p=0.035$), but 3 h treatment increased the strength in all cases ($p\leq0.023$).

Modulus of elasticity changed significantly. Duncan tests showed that significant changes occur at 180°C ($p=0.043$) and 200 °C ($p>0.001$). A 3-hour treatment was significant at 200°C only ($p<0.001$). Based on other studies there is an assumption that modulus of elasticity was affected by material variability and significant decrease is probably lower (Hamyet et al. 2018).

An average Poisson's ratio μ_{RL} of the reference samples was 0.489 (Fig. 2). All treatment cases significantly lowered this value ($p<0.012$), except the 160°C-3h treatment. According to ANOVA, the temperature was the only significant factor ($p<0.001$). Time of treatment and time-temperature interaction were not significant ($p=0.166$ and $p=0.621$, respectively).

An average Poisson ratio μ_{TL} of reference samples was 0.504. This ratio decreased too, but the significant change occurred at 200°C ($p_{1,5hod}=0.040$; $p_{3hod}=0.001$). ANOVA confirmed significant effect of temperature ($p<0.001$). Time of treatment ($p=0.378$) and time-temperature interaction ($p=0.739$) were not significant, similarly to μ_{RL}.

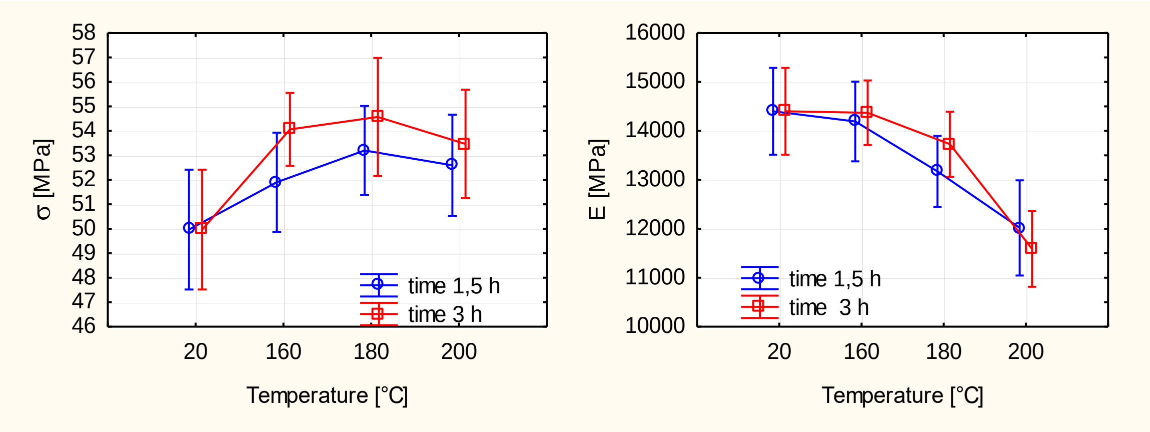

Fig. 1 Compression strength and modulus of elasticity after a thermal treatment. Bars stand for 95% confidential limit.

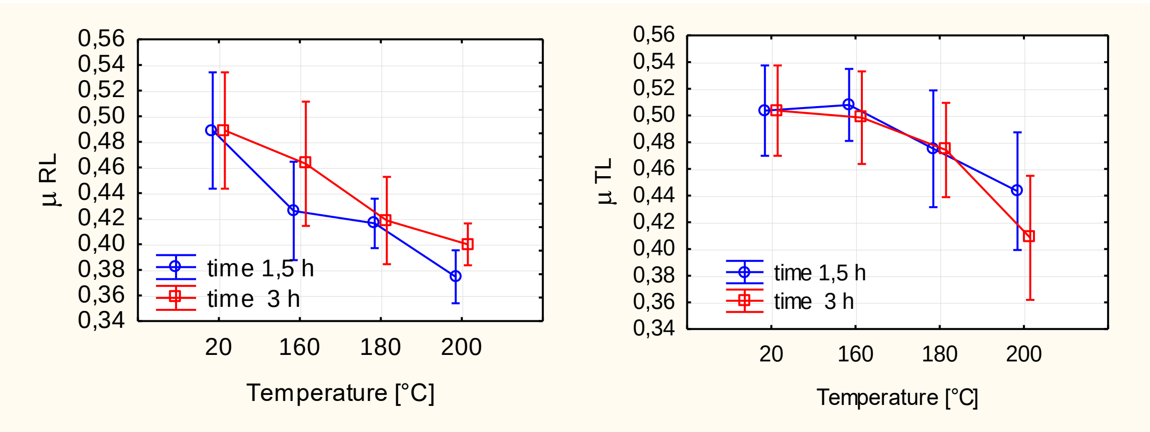

Fig. 2 Poisson's ratios μ_{RL} and μ_{TL} after thermal treatments. Bars stand for 95% confidential limit.

ACKNOWLEDGMENT

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Fracture toughness of thermally modified wood in mode II

Václav Sebera[1,2], Miguel Redon[3], Martin Brabec[1], David Děcký[1], Petr Čermák[1], Jaromír Milch[1], Jan Tippner[1]

[1] Department of Wood Science, Mendel University in Brno, Zemědělská 1, Czech republic
seberav@gmail.com

[2] Innorenew CoE, Livade 6, 6310, Slovenia

[3] Universitat Politécnica de Valencia, Spain

Keywords: fracture toughness, thermal modification, mode II, digital image correlation, end-notched test

ABSTRACT

Thermally modified timber (TMT) has been long recognized as an efficient and eco-friendly alternative to tropical species and wood treated by other techniques. Nevertheless, the range of feasible applications for TMT is limited by undesired side effects, such as reduction of mechanical properties including the fracture properties such fracture energy [BORREGA ET AL. 2008., HUGHES ET AL. 2015, SANDBERG ET AL. 2017). For examination of the fracture properties of wood in shear mode II, there has been developed unique procedure based on so-called equivalent crack length that enables to obtain fracture energies from global mechanical response (YOSHIHARA 2001, WANG ET AL. 2004). This paper aims to evaluate the fracture properties of TMT in mode II by coupling three-point bending test and optical technique based on digital image correlation (DIC).

The fracture toughness of thermally modified timber has been tested against reference non-treated samples of the European beech (*Fagus sylvatica* L.) with dimensions of 20x20x500 mm (radial x tangential x longitudinal length). Nineteen control samples were cut from untreated and the same number was prepared at differently thermally modified (180 °C and 200 °C) which took approximately 50 hours of chamber treatment. Before the sampling, all source material was conditioned in a climate chamber at 20 °C and 65% relative humidity until equilibrium moisture content (EMC) was reached. The test performed was based on the three-point bending end-notched setup in the mode II. An artificial crack length approximately 162 mm was introduced in longitudinal direction. The artificial crack was in LR plane and during testing a Teflon paper was placed inside it to reduce friction. A stochastic pattern to enable DIC calculation was also applied on all the samples prior to the mechanical test. Afterwards, the samples were measured on a universal testing machine. The deformation induced in the samples was determined by the full-field optical stereovision system consisting of two CCD cameras. The images were captured every 0.5 seconds (2 Hz) and synchronized with the applied force. The strain fields at the area of interest from the partial derivatives of the displacement using Lagrange notation were calculated in Vic-3D (Correlated Solutions Inc.). The mechanical responses were processed using compliance-based beam method into calculation energy release rate (G_{II}) and strength [6].

As depicted in Fig. 1, the energy strain rate of the non-treated wood samples is greater than the thermally modified specimens. The statistical analyses showed all three specimen groups have normal distribution of density probability and homogeneous variances. It was found out that all the groups different from one another significantly at a level $\alpha = 0.05$.

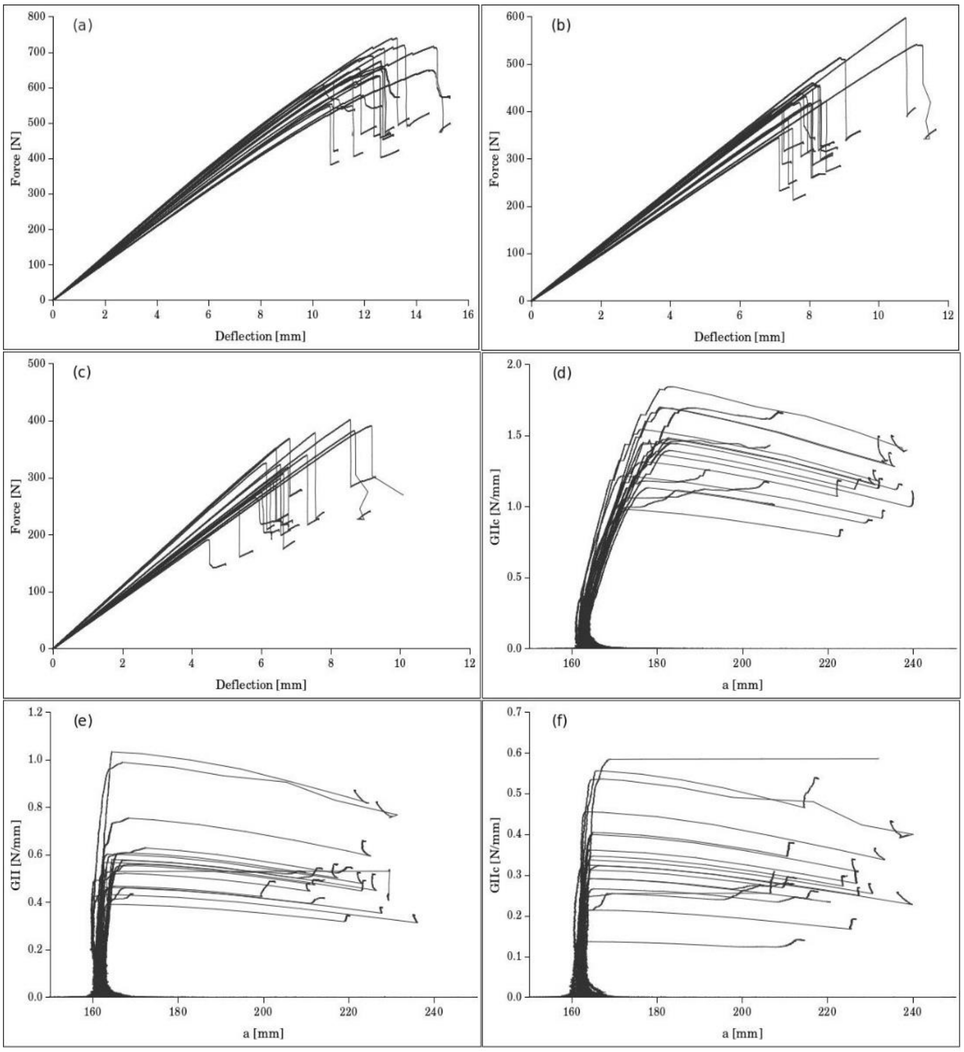

Figure 4: Force-deflection curves for: (a) non-treated wood, (b) treated at 180 °C , (c) treated at 200 °C; Energy release rate dependent on equivalent crack length of: (d) non-treated wood, (e) wood treated at 180 °C, (f) treated at 200 °C

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Static and dynamic performance of wood modified with phenol formaldehyde

Jaka Gašper Pečnik[1], Hannes Schwager[2], Matthew Schwarzkopf[3], Holger Militz[4]

[1] Andrej Marušič Institute, University of Primorska, Koper, Slovenia, jakapecnik@iam.upr.si

[2]University of Göttingen, Wood Biology and Wood Products, Germany, hannes.schwager@forst.uni-goettingen.de

[3]Andrej Marušič Institute, University of Primorska, Koper, Slovenia, InnoRenew CoE, Izola, Slovenia, matthew.schwarzkopf@iam.upr.si

[4]University of Göttingen, Wood Biology and Wood Products, Germany, InnoRenew CoE, Izola, Slovenia, hmilitz@gwdg.de

Keywords: Fatigue life, stress level, phenol formaldehyde, chemical modification

ABSTRACT

Chemical modification of wood is one method to enhance the performance of wood products with respect to water. These modifications are also used to improve mechanical properties under static loads. However, when dynamically loaded to test fatigue, the performance decreases. This fatigue behavior of modified wood under cyclic loading has recently been investigated by several researchers (Gabrielli & Kamke 2010; Sharapov et al. 2016; Ratnasingam & Mutthiah 2016; Yildirim et. al.2015). The objective of our study was to assess how wood modification using phenol-formaldehyde (PF) resins (low and high molecular weight) affected static, highly dynamic, and cyclic loading mechanical performance.
Specimens were prepared using Scots pine (*Pinus sylvestris*) and European beech (*Fagus sylvatica* L.) according to the German standard DIN 52186 (1978) with dimensions of 10 mm × 10 mm × 180 mm (R, T, L). These specimens were randomly distributed into three groups – one modified with a PF resin of low molecular weight (LM), one modified with PF resin of high molecular weight (HM), and one with untreated samples (UN) as a control group. The modification process involved vacuum infiltration of the samples with the PF resins followed by a curing step at 140 °C. Solution uptake (SU) after infiltration, weight percentage gain (WPG), and dimensional changes of the material were determined after curing by measuring the mass and dimensions of the specimens. The modulus of elasticity (MOE) and the modulus of rupture (MOR) were measured in static, three-point bending tests with a Zwick/Roell® universal testing machine. The impact bending strength (IBS) was determined with a CEAST® Charpy impact test device and the cyclic fatigue strength was obtained from a Wöhler fatigue test series with pulsating, sinusoidal loads at 10 Hz on a DHM® test system.
Modification with LM and HM resin resulted in similar effects in both wood types (cf. Table 1). LM groups exhibited high SU and WPG with remarkable dimensional changes in radial and tangential directions due to bulking of the wood structure. By contrast, only minor dimensional changes occurred in HM groups although the solution uptake and the WPG were comparable to the LM groups.
Results of static mechanical testing showed that the performance of wood treated with HM resin did not change considerably compared to UN specimens, while MOE and MOR of LM specimens were much higher. Compared to UN specimens in both pine and beech, the IBS of

HM and LM specimens decreased. The decrease was more evident for samples treated with LM resins. The impact of the modification onto the cyclic fatigue strength (CFS) is comparable to the effect onto the static properties. Minor changes occur in HM group and significant decrease can be observed in the LM group.
Based on our results, chemical modification with high molecular weight PF resin increases the weight of the wood while maintaining its mechanical performance under static, dynamic, and cyclic loading conditions. Modification with a low molecular weight PF resin increases the weight and the mechanical performance under static conditions, but decreases the dynamic and cyclic fatigue properties evidently. These differences in material behavior are most likely due to HM resin only being present in the cell lumen while LM resin was capable of penetrating into the cell walls and interlinking with the wood fibers causing dimensional changes and the augmented static properties. This wood fiber interlinking also increases the brittleness of the material which decreases the dynamic and cyclic fatigue properties.

Table 1: Investigation results (SU – solution uptake, WPG – weight percentage gain, exp_{rad} - expansion in radial direction, exptang – expansion in tangential direction, MOE – modulus of elasticity, MOR – modulus of rupture, IBS – impact bending strength, CFS – cyclic fatigue strength in relation to the modulus of rupture)

	Type	SU %	WPG %	exp_{rad} %	exp_{tang} %	MOE N/mm²	MOR N/mm²	IBS kJ/m²	CFS %
Pine	control		-	-	-	11.783	101,3	15,938	66,6
	HM	104,8	34,9	0,61	0,42	12.319	96,0	9.380	73,1
	LM	133,1	31,7	3,44	1,65	14.814	123,3	6,143	58,0
Beech	control	-	-	-	-	11.817	125,2	18,594	67,2
	HM	104,6	36,2	0,82	1,33	11.355	123,3	15,818	64,5
	LM	100,7	24,2	2,77	8,17	15.248	147,8	11,914	53,5

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Alteration of mechanical properties of ammonia treated and densified beech *(Fagus sylvatica* L.)

Herwig Hackenberg, Mario Zauer, Tobias Dietrich, André Wagenführ

Technische Universität Dresden, Institute of Natural Material Technology, 01062 Dresden
[email: mario.zauer@tu-dresden.de]

Keywords: anhydrous gaseous ammonia, beech, densification, mechanical properties

ABSTRACT

Beech specimens *(Fagus sylvatica* L.*)* have been treated with saturated ammonia gas and subsequently mechanically densified in radial direction. The series of tests can be divided in untreated series, only-ammonia treated (AT) series and ammonia-treated and subsequently densified (ATD) series. The specimens have been treated at isothermal conditions for 0.5 h and 6 h to evaluate the effect of ammonia-treatment. The degree of radial densification was 20% with a subsequent fixation to prevent spring-back. After treatment the specimens have been formatted to the final dimensions 6.5 x 28 x 190 mm³ (R x T x L) and conditioned at 20°C and 65% relative humidity (RH) until they achieved constant mass.

The investigations focused on the alteration of the mechanical properties (absolute bending, bending strength and modulus, respectively). The investigations were conducted by means of a three-point bending test in accordance to DIN EN 310.

Ammonia treatment leads to a known self-densification of the wood cells (Bariska 1975, Coles and Walker 1978). The mechanical densification increases the density additionally which can be seen in Table 1. Density related properties like modulus of rupture (MOR) and modulus of elasticity (MOE) are affected by this alteration. MOR increases by means of higher densities. MOE shows a different characteristic. MOE decreases owing to ammonia treatment, but MOE increases owing to additional mechanical densification.

Table 1: Comparison of determined density, modulus of rupture (MOR) and modulus of elasticity (MOE); median (standard deviation)

Series	Density[a] [kg m^{-3}]	MOR[a] [MPa]	MOE[a] [MPa]
untreated	730 (38)	157 (10)	15600 (1200)
AT 0.5	730 (21)	151 (8)	16100 (1200)
ATD 0.5	860 (36)	162 (10)	16900 (1200)
AT 6.0	920 (26)	175 (11)	14600 (1200)
ATD 6.0	1130 (40)	222 (26)	17600 (850)

[a]determined at conditioned state at 20°C and 65% RH

Additionally to MOR and MOE a further alteration can be observed in bending behaviour. Fig. 1 shows the absolute bending versus bending force. Both AT 0.5 and ATD 0.5 differ only slightly compared to untreated beech. However, AT 6.0 shows a disproportionately increase of deflection, in which MOR increases and MOE decreases. Therefore, AT leads to much more ductile behaviour, this could be connected with stretching of self-densified wood cells. ATD 6.0 shows a much higher ductility with double deflection compared to untreated beech. In this case, both MOR and MOE increase significantly compared to untreated beech. MOR increases almost proportional to absolute bending.

Generally, the investigations show that ammonia treated and following densified beech used gains both higher strength and higher stiffness and simultaneously higher ductility.

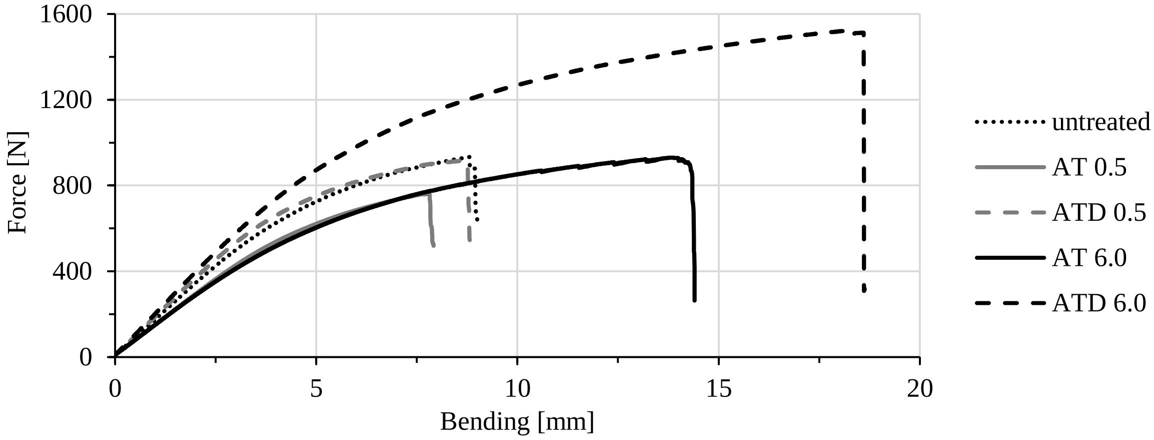

Figure 1: Absolute bending during three-point bending test in accordance to DIN EN 310

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Changes in Hardness as a Result of Longitudinal Wood Compression

Mátyás Báder[1], Róbert Németh[1], Ágnes Vörös[1]

[1] Institute of Wood Science, University of West Hungary, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Sopron, Hungary; E-mail: bader.matyas@uni-sopron.hu; nemeth.robert@uni-sopron.hu, voros.agnes@phd.uni-sopron.hu

Keywords: compression, wood bending, pleating, Janka, Krippel-Pallay, hardness, memory effect.

ABSTRACT

The longitudinal compression of wood (also called as pleating) results in bendable wood (BÁDER AND NÉMETH 2018). With longitudinal wood compression, the required bending force and the modulus of elasticity decrease dramatically and provide great bendability to the wood. The raw material of the experiment was beech (*Fagus sylvatica* L.) and oak wood (*Quercus petraea* (Matt.) Liebl.). The procedure requires high quality hardwood with at least medium density (knot and defect-free, precisely sized, free from cracks and tortuosity, minimal fiber slope, cut from a straight grown tree) as well as the bending of wood. Before compression, the wood has to be plasticized by steaming. The pre-treatment was steaming on 100 °C temperature. The dimensions of the untreated, wet specimens were 20×30×200 mm^3 (R×T×L), determined by the laboratory scale compressing machine. All specimens were compressed by 20% compared to their original lengths. After compression, the treated specimens were relaxed (held compressed for a while in the press) for 1 minute. Before hardness tests, the specimens were conditioned on 20 °C temperature and 65% relative humidity until a constant weight was reached. Specimens with averagely 17×26×30 mm^3 (R×T×L) dimensions were used.
Among the first, Janka (1906) dealt with wood hardness testing, in which he used a steel ball indenter of 11,284 mm diameter. He specified an indentation depth of 5,642 mm, hence the nominal contact area (A) is exactly 100 mm^2. Consequently a load applied (F), so the value of the Janka hardness (H_J) can be calculated by Eq. 1.

$$H_J = \frac{F}{A} = \frac{F}{100} \text{ [N/mm}^2\text{]} \quad (1)$$

During the process, the ball penetrates deep into the examined wood material and often acts as a wedge, so often occur cracks around the indented area and splitting of the specimen as well. But hardness should be measured at a point before fibre failure occurs. The method of Krippel and Pallay (PALLAY 1939) eliminates the disadvantages of the Janka-hardness test, however, it is still not widely known and used. The indenter ball has a diameter of 31,834 mm, which indents the wood surface at a depth of 2 mm. In this case the diameter of the nominal contact area is 15,154 mm, i.e. the area is 200 mm^2. The hardness by the method of Krippel-Pallay (H_{K-P}) can be calculated with the following formula (Eq. 2):

$$H_{K-P} = \frac{F}{200} \text{ [N/mm}^2\text{]} \quad (2)$$

Both Janka and Krippel-Pallay hardness tests were carried out on an Instron 4208 (Instron Corporation, USA) universal material testing machine. The loading rate was 4 mm/min according to Hungarian standard MSZ 6786-11 (1982). The data of the three major anatomical

directions were treated separately. In this experiment, 20 specimens were used in each group, i.e. all average results are from 10 measurements for the *R*, *T* and *L* directions. The aim of this study is the comparison of the hardness of the longitudinally compressed and the untreated specimens.
During the Janka hardness tests, end-grain cracks and splits appeared between the annual rings on almost all specimens, thus the results can not be evaluated. Therefore, only the results of the Krippel-Pallay hardness tests are analyzed in this study. In this case, significant hardness reduction can be seen in the 2 main directions (grain and end-grain) by the longitudinal compression treatment (Table 1).

Table 1: Changes in the Krippel-Pallay hardness as a result of the longitudinal compression treatment

	Difference between the average end-grain hardnesses (%)	Difference between the average grain hardnesses (%)
Oak wood	-24,2	-18,3
Beech wood	-22,3	-2,2

As shown in Table 1, the Krippel-Pallay hardness of oak wood decreased similarly in both main anatomical directions. However, the grain hardness of beech wood reduced only slightly by the treatment. This phenomenon may have anatomical reasons: oak wood has vessels with large diameter in the earlywood with distorted cell walls as a result of the treatment (Báder and Németh 2018) and these vessels collapse more easily during the tests. The other difference is the attendance of very large and also distorted wood rays in oak wood, which may have a hardness-reducing effect. Further examinations are necessary to clarify the reasons.

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Added value and utilization of untreated and heat-treated poplar (*Populus* spp. L.) with and without treatment with N-methylol compounds

Lukas Emmerich[1], Holger Militz[2]

[1]University of Goettingen, Wood Biology and Wood Products, Faculty of Forest Sciences, Buesgenweg 4, D-37077 Goettingen, Germany [lukas.emmerich@uni-goettingen.de]

[2] University of Goettingen, Wood Biology and Wood Products, Faculty of Forest Sciences, Buesgenweg 4, D-37077 Goettingen, Germany [holger.militz@uni-goettingen.de]

Keywords: coating, DMDHEU, hardness, mDMDHEU, processes, weathering

ABSTRACT

The treatment of wood with cyclic N-methylol compounds such as 1.3-dimethylol-4.5-dihydroxyethyleneurea (DMDHEU) has been studied intensively since the 1990s. It was shown to improve in particular the biological durability, moisture resistance and selected physical and mechanical properties of wood. Whereas past investigations focused on the upscaling of this technology for Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.), present research activities work on the transferability to further ‘low-value’ and ‘non-durable’ wood species (EMMERICH ET AL. 2017).

This study reports on the treatability of the ‘non-durable’ and ‘low-density’ hardwood species poplar (*Populus* spp. L.) with DMDHEU and methylolated DMDHEU. In addition, results of outdoor weathering trials (Goettingen, Germany) are presented. Two collectives, untreated and previously heat-treated poplar samples, were chemically modified with DMDHEU and mDMDHEU. Drying and modification quality (DMDHEU distribution and fixation) of the treated material were assessed. The latter was evaluated by the weight gain levels (WPG) and a nitrogen analysis (‘Kjeldahl method’), detecting the nitrogen content [%] before and after a hot-water leaching (90 °C, 16 h). Considering outdoor deckings as a potential application, ‘Brinell hardness’ [N mm^{-2}] following EN 1534 (2011) was tested on the backside of weathering specimens (95 x 30 x 400 mm^3), before outside exposure according to EN 927-3 (2012). Half of the samples over all treatments were coated with a thin-layer coating (pure acrylate). Continuously, cracking on the weathered surfaces was evaluated according to EN ISO 4628-4 (2016) and by a ‘school grade system’, as an adequate, complementary method for assessing cracking of wood from a more practical consumer perspective (GELLERICH ET AL. 2017). Weather induced greying and infestation by staining fungi were recorded by digital scans and digital microscopy (Keyence, VHX-5000). The coating performance was evaluated by a ’pull-off strength’ adhesion test (EN ISO 4624 2016) after 9 months exposure.

By the application of a superheated steam curing process, DMDHEU (WPG 24 – 29 %) and mDMDHEU (WPG 19 – 25 %) treated poplar revealed almost no drying failures in the form of cracking or cell collapse. For mDMDHEU, WPG-levels lay below the ones of the DMDHEU what was confirmed by nitrogen analysis. After a leaching procedure (accelerated ageing) still 80 % of the original nitrogen was measured, what points to a high fixation of the modifying chemical. For methylolated DMDHEU the nitrogen content after leaching was just slightly lower at approx. 72 %.

The ‘Brinell hardness’ of DMDHEU and mDMDHEU treated poplar increased up to 100 % (DMDHEU) compared to untreated controls. In principle, mDMDHEU caused a lower hardness increase. This was confirmed with previously heat-treated poplar since the ‘Brinell hardness’ was not significantly affected by mDMDHEU treatment and only slightly increased by

treatment with DMDHEU (approx. 36 % compared to untreated wood). After 12 months weathering, front sides of modified and untreated boards showed strong differences regarding their macroscopic appearance. Infestation by staining fungi appeared delayed on modified wood surfaces but was not totally prevented. Weathered modified surfaces appeared smooth and in a homogeneous light-grey to grey. Contrary, untreated poplar was grey to dark grey and had rough surfaces with sticking out fibres. This surface appeared patchy with yellow to white spots. The latter was not observed on previously heat-treated poplar surfaces. Those samples showed a 'brightening' from dark-brown to grey. Additionally modified with DMDHEU and mDMDHEU, light grey surfaces were observed after weathering. Compared to untreated wood a slightly increased crack sensitivity was detected after treatment with DMDHEU and mDMDHEU in the form of small and single surface cracks that were found to be 'not critical' from a consumer perspective. The latter were increased by a previous heat treatment but completely prevented by a thin-layer topcoat. The coating adhesion was not negatively affected by the DMDHEU treatment whereas a previous heat-treatment reduced coating adhesion.
In summary, DMDHEU treatment was shown to enhance the in-service material performance of poplar. For the next steps, respective material will be included in durability tests (wood-destroying fungi, marine borer). Considering a high variation in the permeability of poplar and since this is the basis for a homogeneous modification, the 'general treatability' of poplar will be tested by including logs from various forests and provenances within future treatment trials.

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Parallel Session IV.
Machining & Manufacturing

Development of strategies for economic use of bark stripped beech wood

Ruven Hänsler[1], Matthias Zscheile[2]

[1] Hochschulstraße 1, 83024 Rosenheim, Germany, University of applied sciences Rosenheim, ruven.haensler@fh-rosenheim.de

[2] Hochschulstraße 1, 83024 Rosenheim, Germany, University of applied sciences Rosenheim, matthias.zscheile@fh-rosenheim.de

Keywords: Beech trees, Economic use, Bark stripped wood, Fields of application, Game damage, Forest

ABSTRACT

Bark stripping is one of three damages caused by game animals in the forest, besides bite and fraying damages. Generally, it means the process of stripping away the bark of the tree caused by almost every ruminant animal. Typical game animals are the red, sika and fallow deer as well as moose, wisents and mouflons. Thereby the bark constitutes a part of the nutritional intake of the aforementioned species (PRIEN & MÜLLER 2010). Previous studies focused on the analysis of biological consequences of bark peeling using cross-section analysation or a low number of exemplary longitudinal cuts without any statistical significance (WUNSCH 1989, ROEDER 1970).

There is a serious impact of bark stripped wood for the forest owner: (i) deformation of the tree potentially leads to growth depression and bended trunk wood; (ii) predisposed to mushroom and insect enters with potential effects to the entire forest stand; (iii) potentially reduced stability against strong wind and snow events; (iv) economic losses due to lower payments by the wood processing industry caused by supposed unfavourable wood quality. While the first four impacts can hardly be addressed, the wood quality of bark stripped wood against unpeeled wood is being analysed within the joint research project "Strategies for economic use and silvicultural treatment of extremely bark stripped deciduous forests" funded by the FNR to develop strategies of this wood.

In total 120 logs (length: 3,50 m) each of different beech trees (*Fagus sylvatica*) taken from the butt end of the trunk, were grouped into two strength classes (25-34 cm/ 35-49 cm), three categories of bark stripped wounds (closed overgrowth/ overgrowth of open wounds healthy/ overgrowth of open wounds sick) and two different width of the wounds (5-20 cm/ > 20 cm).

At a first stage the logs were visual analysed and damages of the surface were categorized. Second, different cutting and drying processes were applied to determine a replicable maximum yield.

It turned out that the cutting process and the category of wound are very relevant to gain high yield rates. Depending on the cutting the wound surface varies on the sawn wood and thus the yield rate. The drying process whereas shows much less influence on the sawn timber.

Third, the sawn timber is analysed by various material tests, in specific to the bending strength, Brinell hardness and further application specific requirements to categorize possible fields of application of bark stripped beech trees.

By now, a significant difference in dense force as well as bending strength could be determined between bark stripped wood and unpeeled wood.

Forward-looking, the results will contribute to decision making for all participants within the forest-timber value chain, in which extent bark stripping shows negative effects to wood

quality, until which degree damages are acceptable for wood processing, which yield is generally reachable and which scope of application can be expected.

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Development of a new method for calculating the resulting cutting force using beech as an example

Thomas Krenke[1], Carina Rößler[1], Stephan Frömel-Frybort[1],

[1] Division Wood Technologies – Wood K plus – Competence Centre for Wood Composites and Wood Chemistry. Konrad Lorenz Strasse 24, 3430 Tulln, Austria, t.krenke@kplus-wood.at

Keywords: cutting force analysis, wood machining, beech.

ABSTRACT

Essential parts of the mechanical cutting processes in the wood processing industry are primarily designed for the processing of coniferous species. However, due to climatic changes and the resulting conversion of the forest, an increased supply for hardwood is already to be expected. As a result, the wood industry and the wood processing industry are faced with the great challenge of confronting the changing raw materials in good time. For this reason the aim of the research project HARDIS (ATCZ21), financed by Interreg V-A AT/CZ, is to create the basics for a better understanding of machining of hardwood. In the course of the project, a new measuring stand is being developed enabling the investigation of cutting forces and deformation behavior at cutting speeds of up to 100 m/s. In order to be able to validate the measured values of the new measuring stand, a small subproject is the cutting force analysis for rotating cutting processes of hardwood. The aim of this paper is to present the method developed for determining the resulting cutting force using the example of a cutting force analysis of beech.

The cutting force measurements were done on a 5-axis CNC machining center (Venture 115M, Homag, Schopfloch, Germany), with a single-edged cutter (Leitz, Riedau, Austria) at cutting speeds of around 80 m/sec and a feed speed of 15 m/min. The sample was mounted onto the sample holder, which was mounted via 3D-piezo force sensor (260A2, PCB Piezotronics, New York, USA) to the base plate. The chosen sampling rate was 90 kHz. The measurement signal originating from the force sensor was amplified by an extern signal conditioner 482C16 (PCB Piezotronics, New York, USA) and read out over a 4-channel analogue PC input module (16-bit simultaneous resolution) NI 9215 (National Instruments, Salzburg-Bergheim, Austria). The self-developed measurement software is reading and saving the unmodified raw data and plotting the force-curve over the time. The test set up was characterized by means of a transfer function (KRENKE ET AL. 2016). Sample geometry was a cuboid with the cross-sectional area of 60 mm x 60 mm and a length of 100 mm. However, measured values heavily oscillate around zero (fig. 1a) due to the fast tool rotation and the resulting alternating loads (high number of alternations between load and relief). For calculation of an actual resulting cutting force the idea of GOTTLÖBER (2014) was taken into account by integrating the area below the curve.

A self-developed evaluation software automatically imports the stored unmodified raw data and reduces the data in a first process step to the actual process data. In the second process step, the resulting average cutting force $F_{c,m}$ (Formula 1) and the total average cutting force $F_{c,total}$ (Formula 2) are calculated using a fitted envelope function (fig. 1b). As described in the literature, the two resulting cutting forces can be converted into each other on the basis of the process time (t_p) and the actual cutting time (t_e).

Calculated cutting force $F_{c,m}$ is a valuable basis for tool dimensioning and, in case of $F_{c,total}$, a prerequisite for the calculation of the necessary nominal power for drive unit dimensioning.

$$F_{c,m} = \frac{1}{t_p} \times \int_0^{t_p} F_c \times dt \qquad (1)$$

$$F_{c,total} = \frac{1}{t_e} \times \int_0^{t_e} F_c \times dt \quad (2)$$

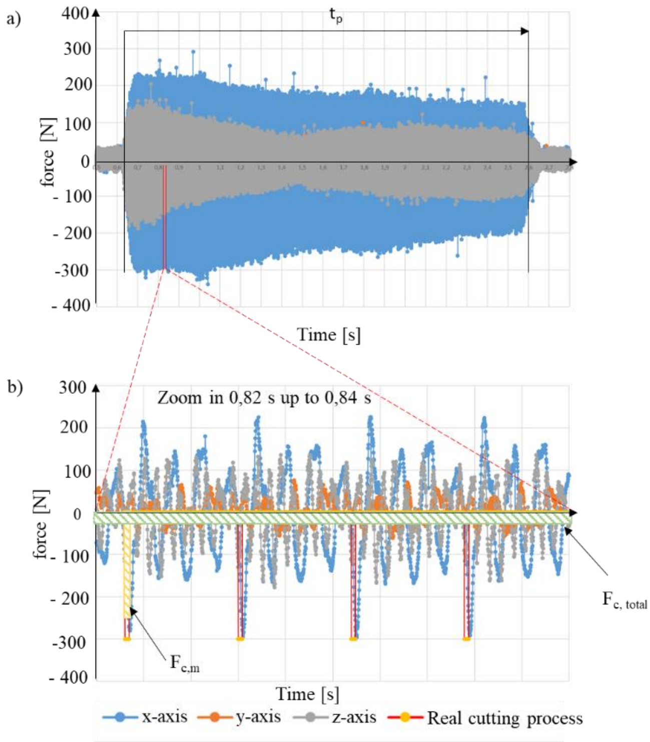

Figure 1 a) unmodified raw data of cutting force analysis of beech on a CNC machining center, with a single-edged cutter (cutting speed around 80 m/sec, feed speed 15 m/min), showing the whole cutting process (t_p). b) zoomed measurement curve in the range of 0.82 s to 0.84 s, showing 4 single cutting processes, which a cutting time of each cut of t_e = 0,19386 ms, resulting in average cutting force ($F_{c,m}$) and average total cutting force ($F_{c,total}$)

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Determination of vibration during milling process of some deciduous wood species

Georgi Kovatchev[1], Valentin Atanasov[2]

[1] 10 KlimentOkhridski Blvd., 1797 Sofia, Building A, office 435, Bulgaria, University of Forestry, Faculty of Forest Industry, e-mail: g_kovachev@ltu.bg

[2] 10 KlimentOkhridski Blvd., 1797 Sofia, Building A, office 435, Bulgaria, University of Forestry, Faculty of Forest Industry, e-mail:vatanasov_2000@ltu.bg

Keywords:wood shapers, milling, cutting mechanism, vibrations

ABSTRACT

This paper presents a study of vibrations during operation of the cutting mechanism in a woodworking shaper. Details from different deciduous tree species, used in furniture production, were milled. During the study some technological factors are being addressed. The exact determination of these regimes is important for the introduction of adequate measures which can guarantee their exploitation. The investigation results can be used as a base for making some recommendations concerning the increase of reliability of the wood shapers as well as the accuracy and quality of their production.

Wood shapers are widespread in practice machines. Their universality allows them to be used in diverse industries in the woodworking and furniture industry. Their main use is in the manufacture of furniture, windows, doors, construction products and many other items used in everyday life. Wood shapers allow different devices to be attached to them. This increases their technological capabilities. Contemporary wood shapers should be able to work at different cutting speed. Most often the speed ranges is between 30 m/s – 60 m/s [Gochev.2005].This inevitably is associated with the machinery resources to work at different rotational speed. They are a precondition for the emergence of different cutting forces that create conditions for loads in the mechanisms which lead to errors during operation [Vukov.2012]. Dynamic effects are constantly changing, which is a premise for permanent shifting loads in the bearings.

To conduct the experimental part, a universal wood shaper with bottom location of the working shaft is selected. The rotation frequency used for the experiments was 6000 min^{-1}. This is one of the most commonly used frequency in milling machines. A cutter with diameter D = 140 mm was used. The feed speeds of the treated material, with which the experiments were made are respectively $U_1 = 4\ m.min^{-1}$, $U_2 = 6\ m.min^{-1}$, $U_3 = 10\ m.min^{-1}$. During the experimental part several wood deciduous species were used (Meranti (*Shorealeprosula*), Koto (*Pterygotamacrocarpa*) and Oak (*Quercuspetraea*). The milling area is accordingly $A_1 = 48\ mm^2$, $A_2 = 96\ mm^2$ and $A_3 = 144\ mm^2$. The intensity of the vibrations is assessed on the basis of the root mean square value of the vibration speed V $mm.s^{-1}$ (r.m.s.) measured at different working modes of the machine. The measurements have been performed at measuring points, located on bearing housings of the main shaft of the machine Fig.1[BDS ISO 10816 – 2002].Vibration speed is measured using a specialized device model Bruel&Kjaer Vibrotest 60 Fig.2.

Influence of feed speed (U) and milling area (a) over vibration speed (v) $mm.s^{-1}$ (r.m.s.)was performed by conducting a planned two-factor regression analysis.The regression equations number 1 and number 2 describe the influence of the studied factors in points Ax and Ay (upper bearing housing, test samples from Koto (*Pterygotamacrocarpa*)).

$$Ax = 1.784+0.140x1+0.098x2-0.067x1x1+0.118x2x2+0.172x1x2 \quad (1)$$

Ay = 2.477+0.035x1-0.175x2+0.095x1x1-0.105x2x2+0.005x1x2 (2)

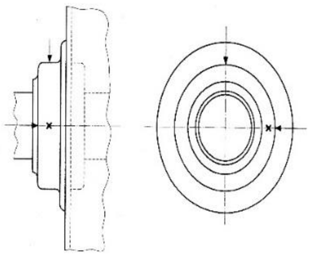

Fig.1. Measurement points

Fig.2.Bruel&KjaerVibrotest 60

Fig.3 and fig.4 shows graphically some of the results.

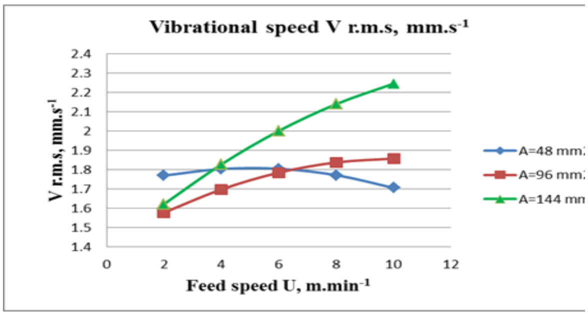

Fig. 3. Vibration speed measured at a point Ax

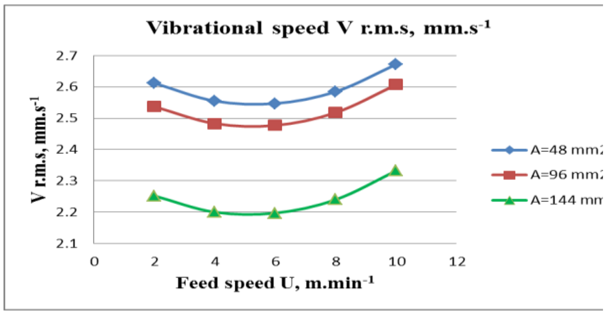

Fig. 4. Vibration speed measured at a point Ay

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Optimisation of Sawing Strategies for Hardwood using a CT-Scanner

Carina Rößler[1*], Jörn Rathke[2], Martin Riegler[1]

[1] Wood K plus - Competence Centre for Wood Composites and Wood Chemistry, Konrad-Lorenz-Straße 24, 3430 Tulln, Austria, c.roessler@kplus-wood.at

[2] MiCROTEC GmbH, Julius Durst Straße 98, 39042 Brixen, Italy

Keywords: sawing pattern, CT-scanning, manual optimisation, wood characteristics

ABSTRACT

The goal was to examine the potential of a CT-Scanner within a mid-sized hardwood sawmill. First, wood characteristics were observed on sawn boards as well as within the CT-images and the corresponding accuracy of detection was evaluated. Furthermore, the difference in value yield between the conventional and the CT-supported procedure was estimated.

Materials and Methods

Twenty logs (ten of beech and ten of oak) were scanned with a CT-Scanner from MiCROTEC. For all logs, the used cutting type was live log sawing. The cutting was realised in a mid-sized hardwood sawmill. Two different strategies for cutting were used (Fig. 1). Five logs of each species were cut according to the conventional procedure, i.e. the operator of the belt saw decides how to cut according to the external characteristics of the log. The other five logs were cut according to the inner characteristics visualised by a computer model obtained from the CT scanner. This procedure will here be called "CT-optimised". For the logs cut in conventional procedure, two optimisation strategies were applied. First, the actual sawing pattern of cutting the logs was reconstructed using a computer model of the log. Second, a theoretical sawing pattern was built, using the information of the CT-scanning. Thus, it was possible to evaluate the effect on the value yield by comparing the results of the two sawing patterns.

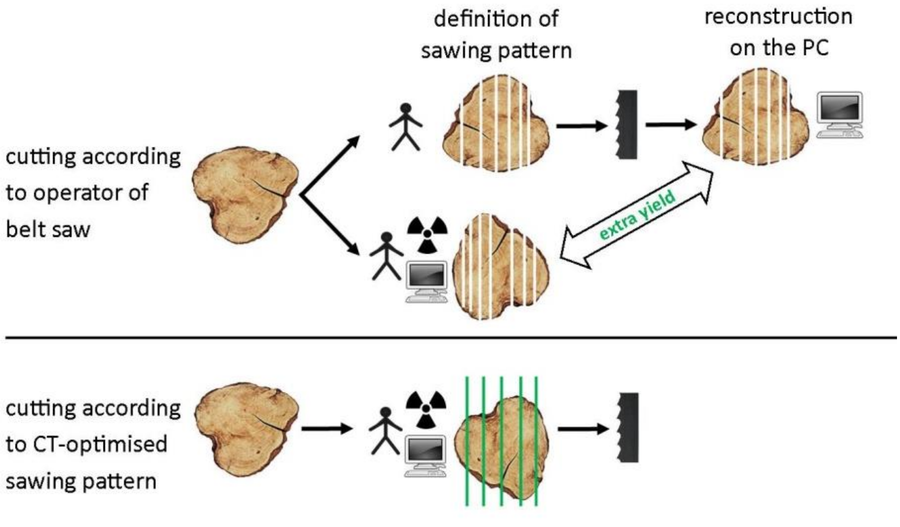

Figure 1: Schematic description of the cutting experiments

The CT-optimised sawing pattern was virtually defined by a manual optimisation through the operator. The goal of this optimisation was to obtain boards with the highest quality. First, the cutting angle was chosen by rating the virtually cut surface of a board at about half the radius of a log (Fig. 2).

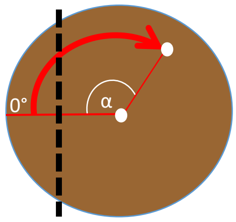

Figure 2: Depiction of choosing the cutting angle

For obtaining non-tapered boards, the logs were axially oriented. Next, the cutting pattern was chosen according to the prescribed dimensions and resulting quality, which was judged according to the images on the PC. The saw kerf was also considered in the definition of the sawing pattern.

Results

The cutting of logs according to the sawing pattern defined on the PC could be realised well. According to the operator of the belt saw, the quality of the boards was generally predicted well by the virtual model based on CT-information (example of red heart wood in a beech log in Fig. 3).

Figure 3: Comparison of wood characteristics within a beech log (left: photo, right: CT-image) ©MiCROTEC

The width of real boards showed good comparability with the width of boards measured on the virtual model on the PC. The classification of boards in reality was similar to the classification based on the virtual model. The CT-optimisation enabled a knowledge based positioning of boards within the logs, to minimise the number of boards containing regions of low wood quality. Thus, a higher number of boards with high quality could be obtained compared to the conventional cutting. The extra value yield with CT-optimisation was calculated according to a given price rating and resulted in 5-10%. This calculated value yield is based on the limited number of 20 logs only. For a reliable number, substantially more logs need to be tested. Nevertheless, the study proved CT-optimisation to be technologically feasible for mid-sized hardwood sawmills.

Influence of veneer specie on the duration of veneering

Dimitar Angelski[1], Vasil Merdzhanov[2], Vladimir Mihailov[3]

[1] University of Forestry –Sofia, Bulgaria, Assoc. professor, PhD, d.angelski@gmail.com

[2] University of Forestry –Sofia, Bulgaria, Assistant professor, PhD, vasilmerdzhanov@gmail.com

[3] University of Forestry –Sofia, Bulgaria, PhD student, vladko86mihailov@gmail

Keywords: veneering, veneer, veneering mode

ABSTRACT

As it's known, the duration of veneering depends mainly on the temperature of the plates, the amount of glue, the wood specie and the thickness of the veneer (KOLLMANN F. ET AL 1975). Due to the relatively small thickness of the veneers (0,5 ÷ 0,6) and high temperature of veneering the influence of the wood species on the duration of the veneer is neglected. Recently, in order to save heat, increasingly veneer is used at relatively low temperatures. Another tendency for veneering is the replacement of urea-formaldehyde with polyvinyl acetate adhesives. The surface and the thickness of the veneer (ANGELSKI AND MERDZHANOV 2010) have a significant influence on the temperature in the area of the adhesive layer. The purpose of the present study is to determine the influence of the veneer specie on the time to reach the veneered temperature to the adhesive layer.

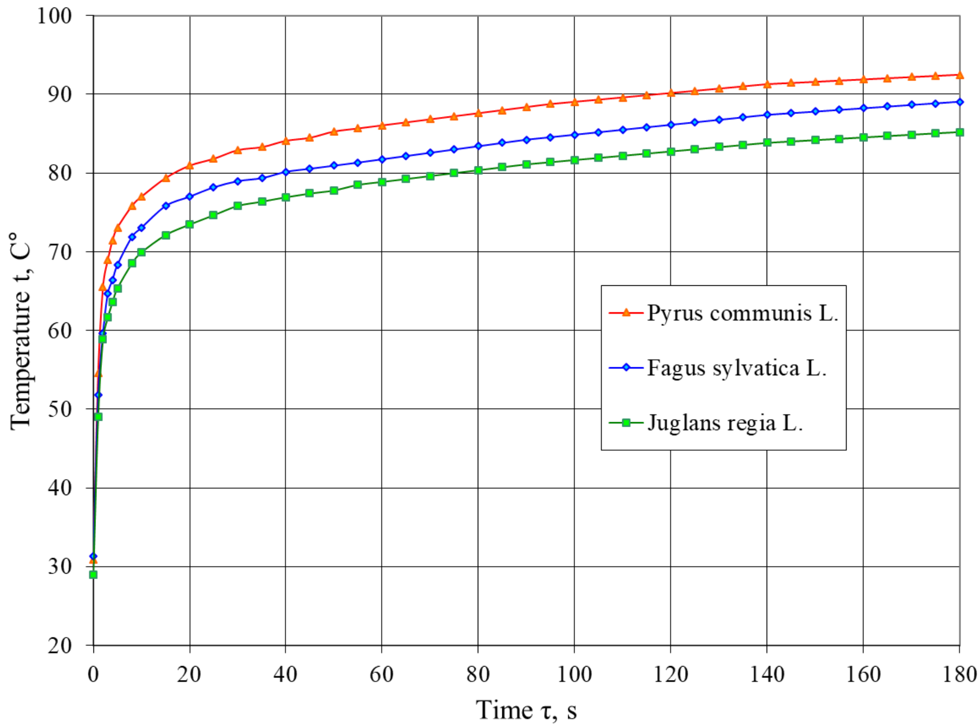

***Figure 1:** Influence of the wood species of deciduous veneers on the time to reach the veneered temperature to the adhesive layer*

The experiments for determining the influence of the wood species on the duration of veneering were made with 6 veneers with 0,6 mm thickness - beech (Fagus sylvatica L.) radial, walnut (Juglans regia L.) tangential, pear (Pyrus communis L.) radial, mahogany (Khaya grandifoliola DC. C.) radial, which (Pterygota macrocarpa K.Schum.) Radial, anigre (Aningeria spp.) Radial.

The temperature of the surface of the countertop and between the particleboard and veneer was measure by thermocouples. The results of the study are graphically represented in Figures 1 and 2 respectively for veneers of deciduous and tropical wood species.

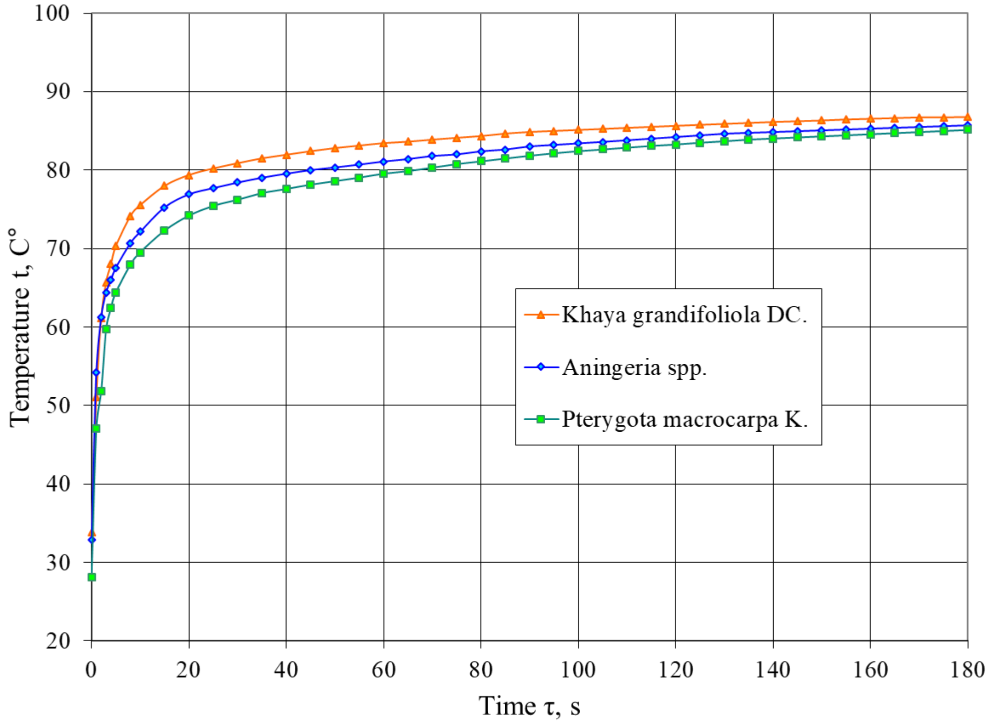

Figure 1: Influence of the wood specie of tropical veneers on the time to reach the veneered temperature to the adhesive layer

Based on the study, the following major conclusions can be made:

- The wood species does not change the nature of the heating process.
- There is a clear correlation between the density of the veneer and the rate of temperature change between the particleboard and the veneer of the deciduous tree species.
- For tropical wood veneers, the correlation between the veneer density and the temperature change rate is less pronounced.
- The influence of veneer specie looks like slowing down or ruining veneering process.

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Enhancing the fire resistance of poplar (*Populus cv. euramericana I214*) by using different fire retardants

Fatima Zohra Brahmia[1], Tibor Alpár[1], Péter Horváth György[1]

[1]University of Sopron, Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Art, Institute of Wood Based Products and Technologies, H-9400 Sopron, Bajcsy-Zs. u. 4.

Keywords: Poplar (*Populus cv. euramericana I214*), Disodium-tetraborate, Disodium-hydrogen phosphate, Diammonuim-hydrogen phosphate, Polyethylene glycol 400, Mass loss.

ABSTRACT

Fire resistance of wood is considered weak. This paper presents the results of some fire retardation experiments on Poplar (*Populus cv. euramericana I214)* by using four different substances with different concentrations (LeVan et al. 1990). Disodium-tetra borate ($Na_2B_4O_7$) with concentration of 25g/l, Disodium-hydrogen phosphate (Na_2HPO_4) with two concentration 25g/l and 77g/l, Diammonuim-hydrogen phosphate ($(NH_2)_4HPO_4$) with concentration of 25g/l and 300g/l and polyethylene glycol 400 (PEG400). Species of poplar (*Populus cv. euramericana I214)* was prepared with three types of surface roughness: sawn, planed and sanded with two different dimension as it is given below (Table 1). For each test 6 samples were made for each surface roughness types and fire retardants. First the specimens were kept in room climate for 7 days after that the surface modification was made by painting 5g of each fire retardants on the surface of the wood by brush. After drying for 24 hours samples were stored in room climate for 7 days. The room climate was set to 20°C of temperature and 65% of humidity to reach 12% of moister content. Two testing methods were applied to investigate the efficiency of these fire retardants. First the single flame source was done as fire test according to standard (ISO 11925-2:2010) *Reaction to fire tests. Ignitability of products subjected to direct impingement of flame. Part 2: Single-flame source test*. Secondly Linder test was done to check the mass loss of the treated samples. In addition, a surface roughness test was made by MAHR S2 perthometer (GURAU AND IRLE 2017). The aim of this study was to investigate the efficiency of the used fire retardants on poplar (RODA 2001) and the effect of the surface roughness on the fire retardation. After examinations, the results showed for surface roughness test the sawn surface is the roughest surface after that come the planned surface then the sanded (Fig. 1). Polyethylene glycol 400 had no good results on all testes. The other fire retardants were effective on poplar but the concentration of fire retardants has big effect on the performance of fire retardation. Higher concentration results higher protection especially in case of Diammonuim-hydrogen phosphate with concentration of 300g/l. In other hand, surface roughness of wood had no significant effect on the fire resistance and on the fire retardant performance (Fig. 2) and (Fig 3).

Table 1: Dimension of used species for each test

Poplar	Length [mm]	Width [mm]	Height [mm]
a	250	90	10
b	100	100	10
c	250	90	10

[a] the single flame source, [b]Linder test, [c] Surface roughness

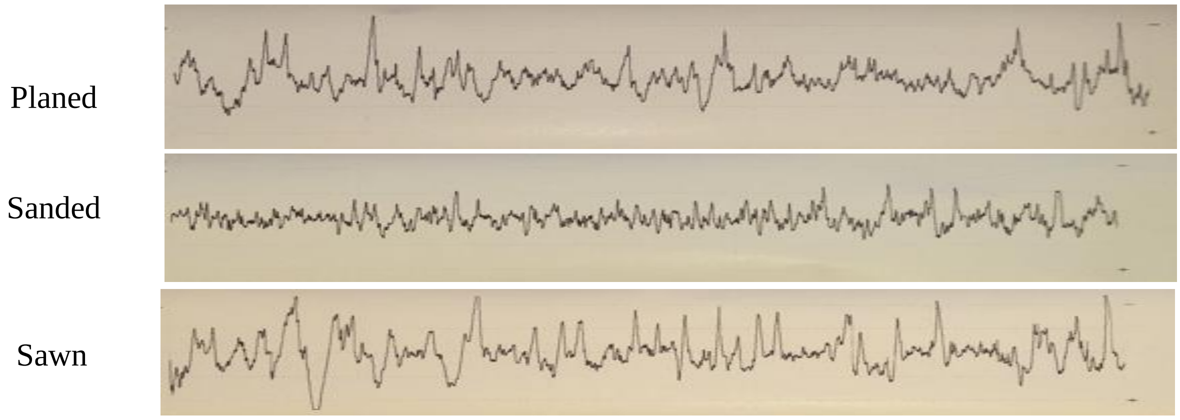

Figure 1: Surface roughness profile of poplar for planed, sanded and sawn surfaces.

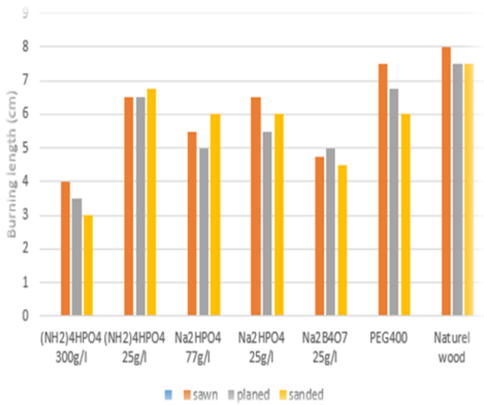

Figure 2: Burning length (cm).

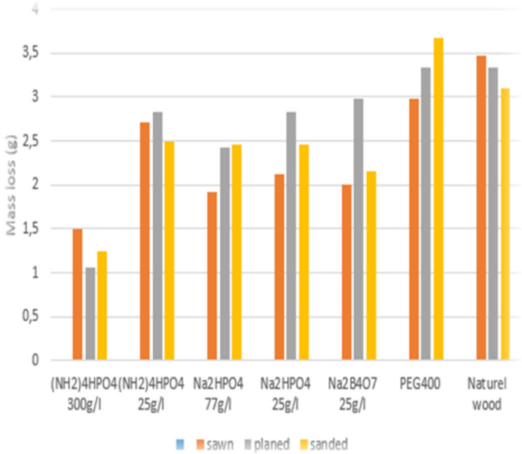

Figure 3: Mass loss (g).

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Parallel Session V.
Wood modification II.

Properties of less valuable parts of beech and sessile oak wood after thermal modification

Nebojša Todorović[1], Zdravko Popović[2], Goran Milić[3], Marko Veizović[4]

[1,2,3,4]University of Belgrade, Faculty of Forestry, Department for Wood Science and Technology, Kneza Višeslava 1, 11030 Belgrade, Serbia

nebojsa.todorovic@sfb.bg.ac.rs

Keywords: beech, sessile oak, thermal modification, sapwood, red heartwood

ABTRACT

Beech and Sessile Oak are very important species for the wood industry in Europe. An interesting part of beechwood is the red heartwood from which less valuable assortments are made. For the oakwood, the sapwood is usually discarded because of bad properties and the potential presence of insects. Thermal treatment of wood can change its color (Bekhta and Neimz 2003), reduce its hygroscopicity and increase durability with a slight reduction of some mechanical properties (Esteves et al. 2008). This points to the necessity to determine whether the wood of the red heartwood of the beech and the sapwood of the oak after the thermal modification differ from the rest of the wood in its color and properties. If there is no significant difference, then it is possible to use these less valuable parts of wood to produce high added value products. On the basis of this, the goal of this paper was to determine the change of color and some properties of thermally modified wood from the area of the red heartwood (beech) and sapwood (oak).

Testing samples (20x20x40 mm) were treated in hot air at the temperatures of 170˚ C, 190˚ C and 210˚ C and the exposure time was 4 hours. Properties were measured prior and after the thermal treatment with conditioning phase (t=23±2° C, φ=50±5 %). Prepared samples were used to determine the physical and mechanical properties of wood: moisture content (EN 13183-1), mass loss (Brischke et al. 2007), color change (CIELab system), compressive strength parallel to the grain (ISO 3132) and Brinell hardness (EN 1534). Color coordinates and hardness were measured at four points on radial surface and average values were used for further calculations.

Table 1: Properties of unmodified (control) and thermally modified sessile oak wood

Wood properties	Sapwood				Heartwood			
	Control	170° C	190° C	210° C	Control	170° C	190° C	210° C
MC (%)	9,8	6,0	4,6	4,0	10,2	5,8	4,4	3,8
WL (%)		1,6	5,4	10,7		1,3	4,1	9,7
CS (N/mm^2)	48,1	47,6	42,5	40,4	57,3	55,2	51,0	49,8
BH (N/mm^2)	27,0	24,8	20,9	20,9	36,1	34,2	31,4	28,4

MC- moisture content, WL – weight loss, CS compressive strength parallel to grain, BH – Brinell hardness

Table 2: Properties of unmodified (control) and thermally modified beech wood

Wood properties	Sapwood				Red heartwood			
	Control	170 ° C	190 ° C	210 ° C	Control	170 ° C	190° C	210° C
MC (%)	9,6	5,6	4,5	3,7	9,2	5,2	4,1	3,2
WL (%)		1,4	4,60	8,5		1,2	3,8	8,5
CS (N/mm^2)	58,0	55,3	53,3	50,5	60,0	55,9	52,3	49,8
BH (N/mm^2)	35,0	32,1	31,0	27,2	35,3	33,6	31,1	26,8

MC- moisture content, WL – weight loss, CS - compressive strength parallel to grain, BH – Brinell hardness

According to the data shown in Tables 1 and 2, the sessile oak heartwood, the beech sapwood andthe red heartwood had approximately the same quality, while the quality of the oak sapwood was slightly lower. For both species, the increase in temperature resulted in a decrease in moisture content, compressive strength and Brinell hardness, while the mass loss increased. The properties of the sessile oak sapwood were significantly different from the properties of its heartwood, while the properties of the beech red heartwood were approximately the values measured in the sapwood. Both species become darker with a rise in temperature. For untreated wood, the difference in color between the sapwood and heartwood parts was greater than 10, indicating an essential color difference before the treatment (Allegretii et al., 2008) (Figure 1).The thermal treatment at the temperature of 190° C resulted in the unification of the color of the beech red heartwood and sapwood. For the oak wood,the treatment at the temperatures of 190° C and 210 ° C only resulted in a reduction of the color difference, but not with the color unification of the heartwood and sapwood samples.

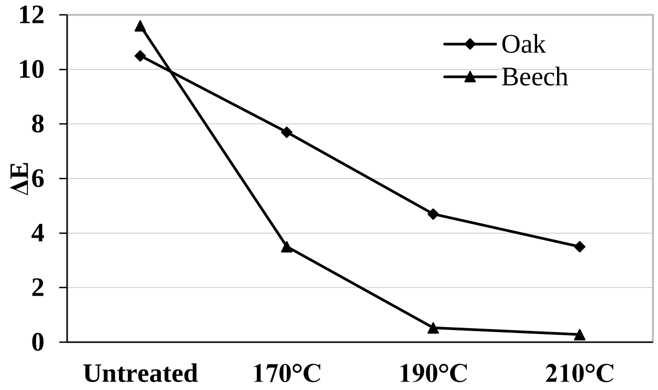

Figure 1:The color difference between the sapwood and the heartwood (red heartwood) for beech and sessile oak before and after the thermal modification

The applied thermal modification has led to a change in the properties of the beech and sessile oak wood. The sapwood and red heartwood of the beech are the same in quality and their color can be equalized at a temperature of 190° C, which is very important from the aspect of the use of the beech red heartwood. The sessile oak sapwood, either treated or not, had lower quality compared to the heartwood part and there was no color unification with the heartwood, even at high temperatures.

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Surface Wetting in Thermally Modified Beech Wood

Jozef Kúdela[1], Tomáš Andor[2], Rastislav Lagaňa[3], Csilla Csiha[4]

[1,2,3] Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovakia; [1] kudela@tuzvo.sk, [2] xandor@tuzvo.sk, [3] lagana@tuzvo.sk

[4] University of Sopron; Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts; Hungary; csiha.csilla@uni-sopron.hu

Keywords: thermal modification, beech wood, wetting, contact angle

ABSTRACT

Thermal wood processing reduces significantly this material´s hygroscopicity. This results in lower equilibrium moisture content values in the sorption process, and in the wood wetting with liquids (1, 2). The capacity of liquids for wetting solid surfaces is assessed based on the contact angle values. Thus the contact angle is a significant indicator in investigating the changes in hygrophilous or hydrophobic performance of wood surface. The contact angle values measured at the interface with a liquid standard also serve as the feature point for determining thermodynamic characteristics of the wood surface – surface free energy and its components (3, 4).

The aim of this work was to evaluate the influence of duration of beech wood thermal modification on its surface wetting with water.

Material and Methods

The experiments were performed on four sets of beech specimens with the radial surface of 50 × 100 mm^2 and the thickness of 15 mm. Immediately before the experiments, the specimen surfaces were sanded with a sand paper grain size P180. One of the sets served as the control one, the other three were oven dried to zero moisture content and subsequently heated at 200 °C for one, three and five hours.

For wood wetting study, we applied on the wood surface a drop of water with volume of 1.8 μl. From the moment of the first contact of a drop until the complete soaking into the substrate, the time-dependent variation in drop profile parallel to the grain direction was scanned with a camera. For this purpose, there was used a goniometer *Krüss DSA30 Standard*. The contact angle θ_0, determined at the beginning of the wetting process, and the equilibrium contact angle θ_e were used for calculating the contact angle value for an ideally smooth surface θ_w. This angle has been recommended for calculating the surface free energy and its components (3).

Results and Discussion

In all cases, the water drop applied on beech wood surface was spreading continually over the surface and at the same time soaking into the substrate.

The best wetting was observed in beech wood before the thermal modification. The mean contact angle value at the moment of drop release θ_0 was 21°, the equilibrium contact angle value θ_e was 13°, and the angle for the ideally smooth surface θ_w was 15° on average. The values of these angles indicate an appropriate wood surface wetting before the thermal processing. The time necessary for complete soaking of the drop into the substrate represented several seconds (Fig.1).

The thermal treatment at 200 °C carried out in three heating periods significantly improved the beech wood surface resistance against wetting with water. This fact is also evident from significantly higher values of all three contact angles θ_0, θ_e and θ_w (Fig.1a). There were also observed longer times necessary for attaining the equilibrium state at the interface between wood and water and for complete soaking of the drop into the wood substrate (Fig.1b). The average contact angle values θ_0 for the relevant heating periods ranged 110°−116°. The average values of the contact angles θ_e and θ_w were in all cases more than 90°. The time necessary for the complete soaking was prolonged several times. The substantially worsened wetting in the thermally processed beech wood is also evident from poorer drop spreading over the wood surface. This difference in wetting was mainly due to the thermal treatment. Duration of the heating period has not been significant factor affecting wettability of treated wood.

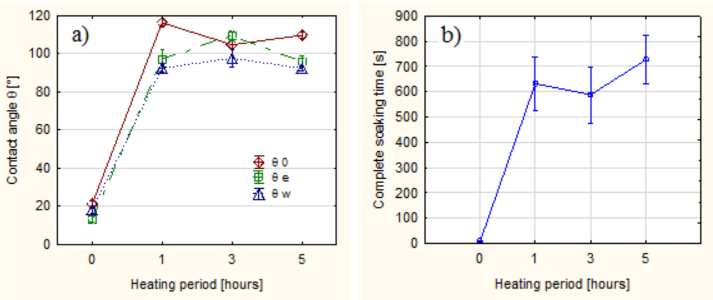

Fig. 1 Duration of heat exposure of beech wood at 200 °C affecting the contact angle values (a) and the time necessary for complete soaking of the drop into the wood substrate (b).

The worsened wetting of wood surface has an important share in lowering its wood surface free energy, which is mainly due to a significant decrease in his energy polar component (2). This fact can impact negatively the surface treatment quality with coating materials applied on thermally treated wood. There still remains an unanswered question about the longevity of the water resistance in thermally modified beech wood.

It could be concluded that the thermal treatment of beech wood at 200 °C significantly improved the wood surface resistance against wetting with water, which could be considered as a profit. It is needed, however, to recognize the longevity of this water resistance and the thermal treatment effects on the wood surface finishing quality.

ACKNOWLEDGEMENT

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Improvement of the dimensional stability of wood by nanosilica treatments

Miklós Bak[1], Róbert Németh[2]

[1,2] University of Sopron; Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts; Hungary; [1] bak.miklos@uni-sopron.hu; [2] nemeth.robert@uni-sopron.hu

Keywords: hygroscopicity; nanoparticles; swelling; anti-swelling-efficiency; swelling anisotropy, water uptake

ABSTRACT

The improving effect of nanoparticles on wood properties is barely known nowadays. Contrarily, the nanoparticles are commonly used in other industries because of their favourable properties. For example, it is possible to improve the properties of polymers remarkably. The novelty of the research is the application of such new nanoparticles, which utilization in the wood industry was not investigated yet.

The expected result of the research is the improvement of the dimensional stability as a result of impregnation with modified silica nanoparticles. Because the wood-water relations are essential at all utilization fields, the expected positive results of the research can serve useful information regarding the expandability of the utilization fields of wood. It is possible to create such dimensionally stable wood material which do not have negative properties as the “price” for outstanding dimensional stability. The effect of two different treatments with silica nanoparticles was investigated on beech wood. One treatment was a pure emulsion of silica nanoparticles (carrier material: ethanol), and another one was silica nanoparticles in tetrahydrofuran carrier material in combination with polydimethylsiloxane (PDMS) as bonding agent. PDMS was used as bonding agent to improve the bonding of the silica nanoparticles to the wood structure.

With the use of the modified hydrophobic silica nanoparticles (SiO_2), it is possible to improve dimensional stability of wood. Shrinking and swelling properties decreased remarkably, depending on treatment type (Fig. 1). The ASE was similar in radial and tangential direction. Application of PDMS did not provide better dimensional stability compared to the treatment without it, which is explained by the lower amount of hydrophobic nanoparticles in this case, but compensated by the hydrophobic properties of PDMS itself.

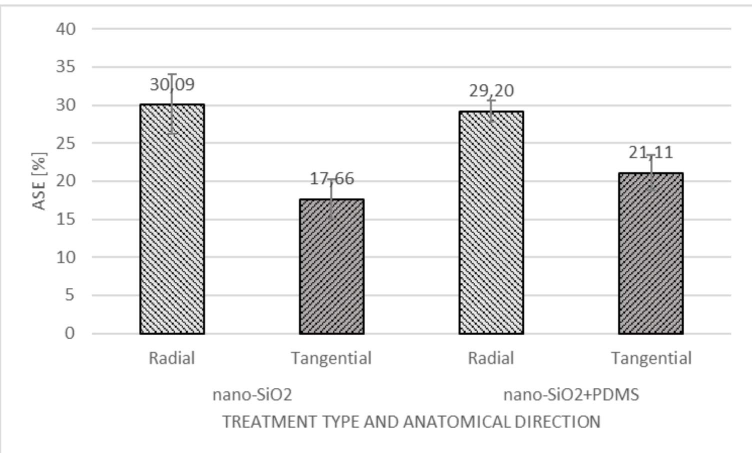

Figure 1: ASE of nano-silica treatments on beech wood (whiskers showing standard deviation of the results)

Swelling anisotropy was increased slightly, but insignificantly as a result of the treatment, as slightly higher ASE was observed in radial direction, compared to tangential. With the use of PDMS slightly lower EMC and highly lower water uptake compared to the basic "nano-SiO_2" treatment was observed. The improved hydrophobicity of the cell wall surfaces through the deposition of silica nanoparticles make the investigated treatments more effective against liquid water, compared to water vapour. SEM imaging showed that the distribution of the nanoparticles is mostly even on the cell wall surfaces, but some deposits and agglomerations were found as well. As a side effect of the treatments, a well visible colour change in the form of darkening/fading occurred.

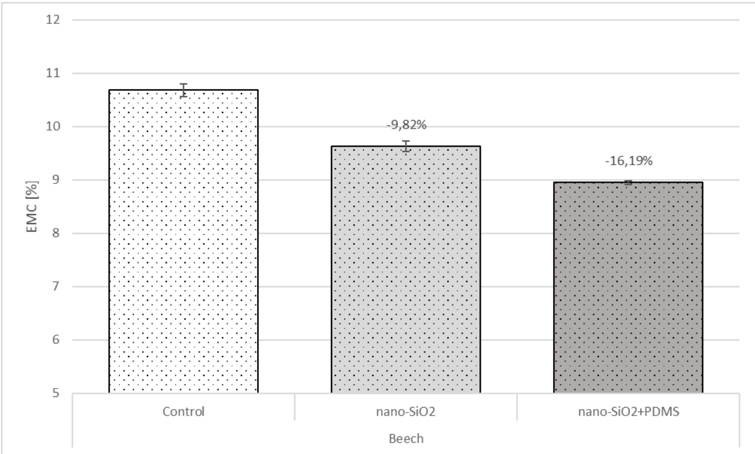

Figure 2: Effect of nano-silica treatments on the equilibrium moisture content of beech and scots pine wood (percentages showing the difference to the control and whiskers the standard deviation of the results)

ACKNOWLEDGEMENT

This research was supported by the National Research, Development and Innovation Office - NKFIH, in the framework of the project OTKA PD 116635 with the title "Improvement of the most important wood properties with nanoparticles".

FTIR Analysis of Densified and Steamed Beech Wood

Radim Rousek[1]

[1] Department of Wood Science, Faculty of Forestry and Wood Technology, Mendel University in Brno, Czech Republic; E-mail: radim.rousek@mendelu.cz

Keywords: wood compression, densification, set recovery, FTIR

ABSTRACT

Compression of wood in transversal direction has been investigated by many scientists. The process is known to improve mechanical properties (NAVI AND SANDBERG 2012). However; the challenging part of the research is to make such material stable in wet conditions. The most promising method to reduce compression set recovery is post-treatment in saturated steam (KUTNAR AND KAMKE 2012, ROUSEK AND HORÁČEK 2016). The chemical changes in wood responsible for stabilisation are not sufficiently explained. It could be not only hydrolysis of hemicelluloses (INOUE ET AL. 2008) but also formation of new bonds in insoluble compounds of wood. One of the most suitable methods for analysis of chemical bonds in wood is FTIR spectroscopy (TOLVAJ ET AL. 2011). The aim of this research is to analyse the influence of compression and steaming on chemical bonds in wood with using standard FTIR spectrometer and IR microscope.

Beech wood (*Fagus sylvatica* L.) specimens with dimensions 40×15×150 mm^3 (R×T×L) were soaked with water, plasticized with microwaves and compressed in tangential direction. Compressed specimens were fixed in special stainless steel clamps and post-treated in saturated steam in a closed vessel. The conditions were 90°C for 6 days and subsequently 100°C for one day. Four different groups of specimens were prepared: untreated, compressed and dried, compressed and steamed and steamed without compression. This material was cut into small specimens with dimensions 5×10×20 mm^3 (R×T×L). The surface was microtomed.

The FTIR spectra were measured with JASCO FT/IR-6300 spectrometer and JASCO IRT-5000 infra-red microscope (Fig. 1). The final spectrum of each sample was the average of 50 measurements on tangential surface. Processed spectra were compared by subtracting them and differential spectra were prepared.

Figure 1: JASCO IRT-5000 infra-red microscope and JASCO FT/IR-6300 spectrometer (University of Sopron)

The data evaluation is in progress at the time of the abstract submission. Final results will be presented at the conference. First analysis of the data showed significant differences between untreated and steamed specimens. However the measured spectra can be affected by density and roughness of the specimens and need to be normalized before comparing them.

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Photodegradation of acetylated wood irradiated by xenon lamp and mercury-vapour lamp

Fanni Fodor[1], Róbert Németh[2]

[1] Institute of Wood Science, Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts, University of Sopron, Bajcsy-Zs. u. 4. Sopron 9400, Hungary, fodor.fanni@phd.uni-sopron.hu

[2] Institute of Wood Science, Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts, University of Sopron, Bajcsy-Zs. u. 4. Sopron 9400, Hungary, nemeth.robert@uni-sopron.hu

Keywords: photodegradation, acetylation, wood modification, hornbeam, irradiation, colour

ABSTRACT

The colour of wood changes if it is exposed to ultraviolet (UV) light or thermal impact. The colour can be objectively determined with various methods. In this work, CIELAB colour system was used where L* defines lightness (0 is black and 100 is white), a* denotes red/green hue (positive values for red and negative values for green), and b* denotes yellow/blue hue (positive values for yellow and negative for blue). The colour change of wooden products can be determined by calculating the change in colour components (ΔL, Δa, Δb) and then the total colour difference (ΔE*). It should be noted that the difference between wooden surfaces cannot be noticed just because of the colour change but also of the inhomogeneity of wood itself (vessels, tyloses, ray flecks, grain structure, early and latewood transition).

The advantage of artificial ageing is the reproducibility of the measurements, the constant settings and the short testing time. Only photodegradation occurs unlike in case of weather exposure. In this test, artificial lightsources are used: xenon lamp and mercury-vapour lamp. Unlike xenon lamp, the mercury-vapour lamp emits light in all UV regions: 80% of its emission is UV light, from which 31% is UV-A (380-315 nm) region, 24% is UV-B (315-280 nm) region and 25% is UV-C (> 280 nm) region. The xenon lamp emits UV light only in UV-A region (400-340 nm).

Acetylation is a chemical wood modification method, which improves the durability, dimensional stability and strength of wood without the material being toxic to the environment. Acetylation is reported to increase the weather (light and moisture) resistance of wood, noting that the photostability increases at higher WPG (Weight Percentage Gain) levels. However, acetylated wood only shows initial stability against UV radiation, later it begins to fade and grey. Although acetylated wood is less susceptible to moisture and has better dimensional stability, acetylating the phenolic OH groups, which retard the formation of quinones, reduce the protective mechanism against photodegradation. This makes acetylated wood vulnerable to colour change, greying even at high WPG levels (FODOR AND NÉMETH 2017).

For the tests, hornbeam boards were obtained from the southwest part of Hungary. The air-dry density varied between 750-790 kg/m^3. Half of the hornbeam boards were acetylated at Accsys Technologies (Netherlands) under industrial conditions. The average WPG was 15%. The samples were of 20 × 20 × 100 mm^3 (t × w × l) with tangential surface.

The UV irradiation was carried out in an ageing machine at the Department of Physics and Electronics at the University of Sopron. There were two mercury-vapour lamps with 76W/m^2 average radiant power density used in one test, and two xenon lamps with 482W/m^2 average radiant power density used in the other test. The lamps were 64 cm above the samples and the temperature of the equipment was set to a maximum of 50°C (of course, the temperature of the samples was higher).

The colour was determined with Konica Minolta 2600d spectrophotometer. There were a total of 20 measuring points for each test. The colour was determined after 0-5-10-20-30-60-120-200 hours of irradiation.
Already after 5 hours of irradiation, the colour changed remarkably, over time, the rate of colour change decreased. During irradiation, hornbeam’s light colour became darker yellow: the lightness decreased while the red and yellow hue increased. Acetylated hornbeam’s dark greyish brown colour brightened greatly as a result of irradiation: the lightness increased, the red and yellow hue decreased. Exposure to xenon lamp had greater impact on the colour of both wood types than mercury-vapour lamp which can be explained by the fact that the radiant power density of xenon lamp was more than six times bigger.
Among the weathering factors, the sunlight (UV radiation) causes the greatest change in the colour and the surface. Irradiating with mercury-vapour lamp and xenon lamp can help study the photodegradation mechanism in wood but it cannot simulate natural sunlight (TOLVAJ AND VARGA 2012). The brightening of acetylated hornbeam is probably associated with the extractive content. After acetylation, the extractive content of hornbeam increased which transformed during UV irradiation thus influence the colour. Lignin also degraded as a result of irradiation (FODOR AND NÉMETH 2017).

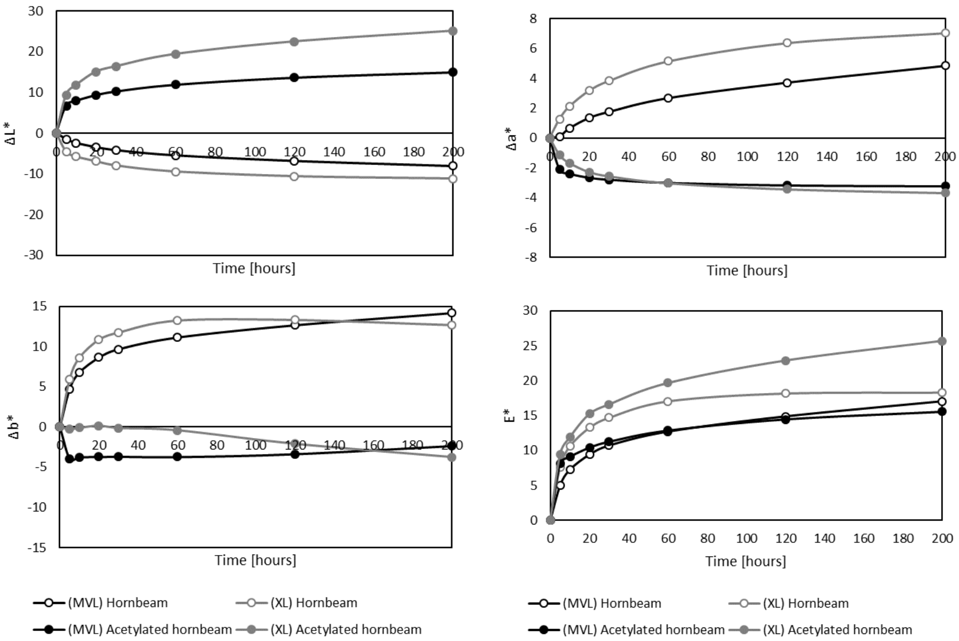

Figure 1: Change of colour coordinates (L* - lightness, a* - red hue, b* - yellow hue) and total colour change (E*) of untreated and acetylated hornbeam irradiated by mercury-vapour lamp (MVL) and xenon lamp (XL) for 200 hours

This work was supported by the ÚNKP-16-3-1 and ÚNKP-17-3-I New National Excellence Program of the Ministry of Human Capacities in Hungary.

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Effect of High Intensity Microwaves to Hardwood Structure Modification and Its Applications in Technology

Grigory Torgovnikov and Peter Vinden

University of Melbourne, 4 Water St., Creswick, Victoria 3363, Australia [e-mails: grigori@unimelb.edu.au ; pvinden@unimelb.edu.au]

Keywords: microwave wood modification, Torgvin, Vintorg, wood permeability, wood structure.

ABSTRACT

A number of hardwood species have a very low permeability causing problems during timber processing. These include, very long drying times, expensive drying processes and difficult impregnation with preservatives and resins. Furthermore, growth stresses in wood and collapse often leads to drying defects and high material losses in the recovery of sawn timber. In the wood pulping industry low wood permeability results in shallow chemical penetration of pulping liquids into wood. This requires the use of small sized chips, high chemical usage and high energy consumption. MW wood modification can provide an increase in wood permeability, that solves many wood processing problems.

This study of MW wood modification investigates: the effects of MW modification on elements of wood structure at macro and micro levels, process parameters for MW wood treatment, prospective commercial applications of MW technology.

Intensive MW power applied to green wood generates steam pressure within the wood cells. Under high internal pressure the pit membranes in cell walls, tyloses in vessels and weak ray cells are ruptured to form pathways for easy transportation of liquids and vapours. An increase in the intensity of the microwave energy increases the internal pressure, resulting in the formation of narrow voids in the radial-longitudinal planes VINDEN AT Al. 2003). Such wood modification requires applied MW energy levels from 250 up to 1200 MJ/m^3 (at frequencies 0.922 and 2.45 GHz) depending on wood species physical properties.

Three MW plants were used for experiments: 60 kW plant at 2.45 GHz, 60 kW plant at 0.922 GHz and a 300 kW plant at 0.922 GHz. Every MW plant possessed 4 sub-systems: MW sub-system generators with product specific MW applicators, timber feeding sub-system, air dynamic sub-system is designed to remove vapors, water and wood particles from the applicator, and control and operation sub-system.The specific power applied to the wood at 2.45 GHz was in the range from 5,000 to 135,000 kW/m^3. At a frequency of 0.922 GHz a range of 5,200 to 26,000 kW/m^3 was used (TORGOVNIKOV and VINDEN 2009).

It was found that the wood structure of 4 different softwood and 13 hardwood species tested can be MW modified to increase wood permeability. It is possible to classify (tentatively) three degrees of the wood modification which depend on the MW processing conditions: Low, Moderate and High degree. Fig.1 illustrates different degrees of modification.

Low degree of MW modification can increase wood permeability in the range of 1.5-10 times. Moderate degree of modification can increase the permeability a thousand fold. While a High degree of modification can convert wood into a highly porous material with numerous cavities mainly in the radial – longitudinal planes and permeability increases dramatically compared to natural wood. High degree modification can convert wood into a highly porous material with numerous cavities mainly in the radial – longitudinal planes and permeability increases dramatically compared to natural wood. This porous material was named “Torgvin”.

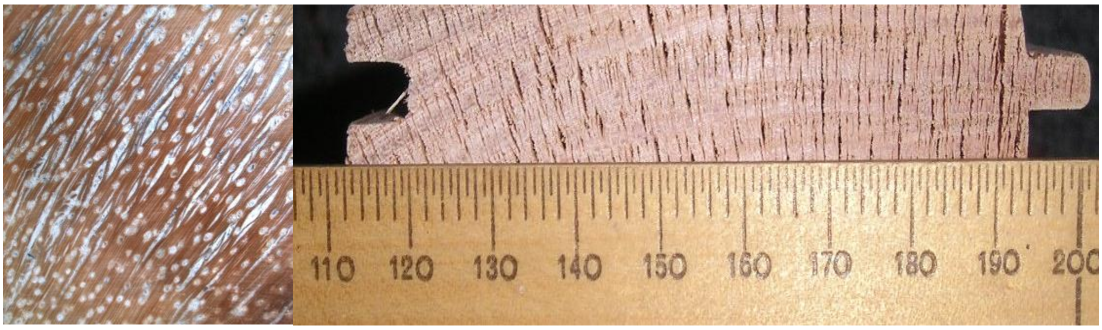

Figure 1. Blue gum wood cross cut (left) after Moderate degree MW modification. Narrow white lines are original rays, wider white lines are ruptured rays. Mountain Ash (right) wood structure after High degree MW modification.

Changes in the wood structure revises wood properties. The most important change is the dramatic increase in wood permeability. Impermeable and low permeable species transform into highly permeable materials that can allow the flow of liquids and gases within its structure. Low degree of modification does not change noticeably wood density and strength properties. High degree of modification diminishes wood density, modulus of elasticity and modulus of rupture significantly depending on applied MW energy. The wood strength reduction after processing in the tangential direction is higher compared to the radial direction.
It is possible to use microwave wood modification to enhance existing processes and to develop entirely new processing and product options for wood. The study on MW wood modification allowed the identification of six main commercial applications for the technology:

- the treatment of refractory wood species with preservatives,
- pre-drying treatment of hardwoods for rapid drying,
- growth and drying stress relief in timber,
- manufacturing of new wood materials Torgvin and Vintorg,
- improvement of wood pulping properties by MW modifying logs, sawn timber and woodchips,
- use in manufacturing "superwood" with mechanical properties higher than steel.

The cost of MW wood modification was found to be in the range of AU$ 28-69/m^3. This is acceptable for industry and provides good opportunities for commercialization.

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Parallel Session VI.
Hardwood in composites and engineered materials

Utilization of Lesser Known and Lesser Used Hardwoods for Decorative Veneers Purposes

Roman Réh[1]

[1] Technical University in Zvolen, Faculty of Wood Science and Technology,
Department of Mechanical Technology of Wood, T. G. Masaryka 24, 960 53 Zvolen, Slovak Republic,
tel.: +421 45 5206 384, fax: +421 45 5321 811, roman.reh@tuzvo.sk

Keywords: lesser known and lesser used hardwoods, decorative veneers, bio-based composites, veneer properties, veneering

ABSTRACT

Hardwoods have been used by societies around the world for thousands of years. Together with advantageous structural use of hardwoods, humankind has also realized that there are essential decorative features of hardwoods. Enhanced woodworking technology and, in particular, the development of slicing have made advances in the use of decorative veneers. A decorative veneer use includes creating the appearance of solid wood to furniture, doors or various architectural elements of a space. Popularly used species of hardwood veneers include oak, cherry, maple, birch, ash, walnut and some more species. The purpose of this long-term research was to test other hardwoods for decorative veneer purposes, particularly lesser known and lesser used hardwoods. Decorative veneers made from these hardwoods must meet the highest demands on workability and aesthetics.

These were the following types of hardwoods that have undergone research at the Technical University in Zvolen in order to recommend appropriate technological parameters for their processing and to test their physical, mechanical and technological properties of decorative veneers:

- Red oak (*Quercus rubra* L.)
- Black walnut (*Juglans nigra* L.)
- Sweet chestnut (*Castanea sativa* Miller)
- Black locust (*Robinia pseudoacacia* L.)
- Silver maple (*Acer saccharinum* L.)
- Butternut (*Juglans cinerea* L.)
- Ailanthus (*Ailanthus altissima* (Miller) Swingle)

Logs (raw material) for this research have Slovak origin, all of them are introduced species on the territory of Slovakia. From 8 to 10 veneer logs per every species with a length of 140 +/- 3 cm and a diameter of 25–42 cm were heated or placed into the water after their transport for soaking and consequently the logs were debarked and processed. Decorative veneers were manufactured by the method of off-center cutting in the Development workshops and laboratories of the Technical University in Zvolen (Slovakia). By means of interrupted off-center cutting, new and interesting grains and textures of hardwood veneers were obtained. Veneers with the thicknesses of 0.6, 0.7, 0.8 or 0.9 mm were dried up to a moisture content of 12+/-3 % by drying at a temperature of 100-130 °C in the belt (mesh) dryer.

Harwood veneers were subjected to a number of technological test procedures.

1) Specific glue penetration to the veneered area
2) Veneer adhesion to the particleboard substrate (surface soundness)
3) Technological properties of veneer from the aspect of surface finish
    a) Determination the local thickness of the paint.
    b) Determination of the paint adhesion by means of the screen method (cross hatch).

c) Determination of paint hardness by means of the pencil method.
d) Determination of the resistance to hot steam.
e) Determination of the resistance to a burning cigarette (burn resistance).
f) Determination of the resistance to chemicals and selected consume liquids (spot resistance).
g) Light fastness.

The technological properties of decorative veneers were tested for surface finish by transparent paints and systems commonly used for finishing in the furniture industry (nitrocellulose or synthetic acid hardening lacquers).

The popularity of decorative veneers is increasing globally and permanently. From the results of the long term research performed it can be said that lesser known and lesser used hardwoods are fully recommended for veneer and furniture industry. Lesser known and lesser used hardwoods tested have interesting decorative figure and they can have a rare effect. The quality of veneer made from lesser known and lesser used hardwoods does not differ from the quality of commonly used veneers and the veneer thickness of 0.6–0.7–0.8 mm can be recommended for furniture industry. Glue spread rate of 130–140 $g \cdot m^{-2}$ was proposed for particleboards.

Selected introduced wood species suggest good perspectives in the coming years. Future quality of wood and volume production may be secured by the providing of systematic and intense tending of forest stands. Lesser known and lesser used hardwoods decorative veneers are suitable for commonly used paint systems and given transparent paint systems it may be judged as equivalent and suitable for furniture-making. Lesser known and lesser used hardwoods are suitable for application in the furniture industry either as a replacement for some commonly used wood species or as a wood species widening the assortment of wood species utilized in furniture industry. The results obtained suggest that it is possible to recommend its cultivation in larger areas upon properly managed stands. It is still necessary to gather more accurate data on the nearest zoning in Central Europe and to realize a research of consumer market in the field of utilizing decorative veneer made from lesser known and lesser used hardwoods.

ACKNOWLEDGEMENT

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Production of peeled veneer from black locust Pretreatment - Production - Properties

Peter Meinlschmidt[1], Christian Dittrich[1], Dirk Berthold[1]

[1]Fraunhofer Institute for Wood Research / Fraunhofer WKI

Department Technology for Wood-Based Materials

D-38108 Braunschweig, Bienroder Weg 5E, Germany

peter.meinlschmidt@wki.fraunhofer.de

Keywords: Peeled veneer, pretreatment, lathe checks, surface roughness, colour changes

ABSTRACT

On a global scale, the cultivation of the nitrogen-fixing tree Robinia pseudoacacia L. (black locust) gains more and more importance in forestry and agro-forestry systems. Black locust is native to south-eastern North America, yet worldwide the land area covered by black locust stands has enlarged drastically to about 3 million ha, an area only exceeded by that of Eucalyptus and Poplar (HANOVER ET AL. 1991). In Europe, Hungary is the largest producer of black locust timber. The area under black locust stands there is projected to increase from 320.000 to 360.000 ha in the next twenty years (MOLNÁR 1994).

Black locust is a multipurpose tree, though it primarily is used for erosion control and reclamation of disturbed areas due to its tolerance against drought and severe frosts, its high vitality and regeneration ability and the fixation of atmospheric nitrogen. It is also increasingly profitable and cultivated in short rotation plantations outside of its natural range because of its fast growth compared to other tree species, especially under nutrient deficient soil conditions, its easy and cheap stand regeneration from root suckers and stem sprouts, as well as its excellent wood properties.

Black locust is growing in increasing quantity all over Europe. Even it is whether managed properly nor intensively used in most of the EU countries it is an interesting wood species because of its durability and aesthetic appearance. In this way, recently IKEA produces more and more garden furniture made from black locust instead from tropical woods.

At WKI intensive tests (DITTRICH 2017) were executed on the new RAUTE peeling machine (Fig. 1) to find out under which conditions the peeling of good quality veneer from black locust can be done and what properties of the veneer can be reached.

Figure 1: A Robinia log in the cooking unit (left) and the new RAUTE peeling machine at the WKI (right)

Correlations between cooking temperature and time (DUPLEIX ET AL. 2013) versus colour, surface roughness (DUNDAR ET AL. 2008), as well as frequency and depths of lathe checks (Fig. 2) will be demonstrated.

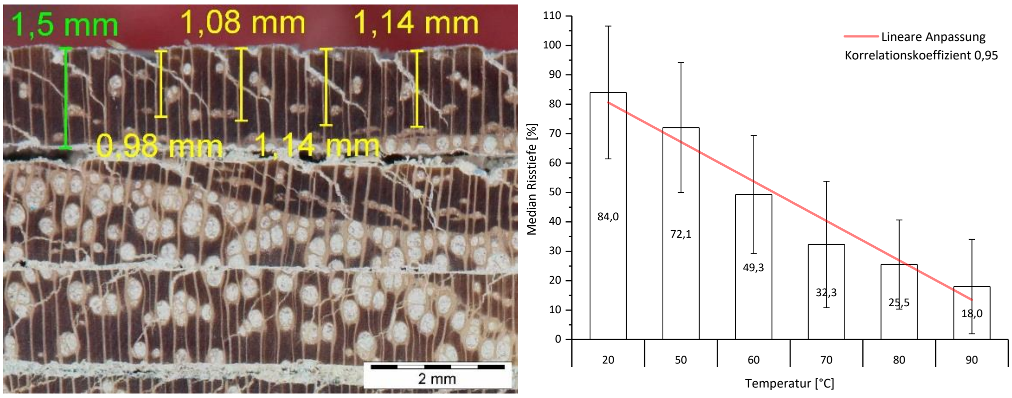

Figure 2: Measurement of the lathe checks depths (left) and the correlation between the medium depths and the cooking temperature of the black locust log.

First bonding tests between veneer from black locust and from other species like beech and spruce will complete the presentation.

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Factors influencing cold tack development during the production of birch plywood

Elfriede Hogger[1], Wolfgang Kantner[2], Johann Moser[2], Johannes Konnerth[3], Hendrikus W. G. van Herwijnen[1]

[1] Wood K plus, Competence Centre for Wood Composites and Wood chemistry, Altenberger Straße 69, 4040 Linz, Austria, WMT, e.herwijnen@kplus-wood.at

[2] Metadynea Austria GmbH, Hafenstrasse 77, 3500 Krems, Austria

[3] Institute of Wood Technology and Renewable Materials, University of Natural Resources and Applied Life Science, Konrad Lorenz Strasse 24, 3430 Tulln, Austria

Keywords: Cold tack, plywood, birch

ABSTRACT

Birch plywood is a high quality material for applications requiring high strength and rigidity. Tack of a resin is defined as the property to form a bond immediately when in contact with another surface (EN923, 2005). This resin property is of great importance for the production of birch plywood. If cold tack fails, the stack opens, does not fit into the press, and cannot be processed. Insufficient cold tack is usually considered a typical adhesive problem.

For particle board application it was shown that drying out of a urea-formaldehyde (UF) resin is a key factor for the development of cold tack (HIMSEL ET AL, 2016). Therefore, focus of this study was put on the systematic investigation of factors that are expected to be related to drying out, such as lay-up time, resin amount, wood moisture content, veneer temperature, and pre-press time. Furthermore, also the resin age was investigated.

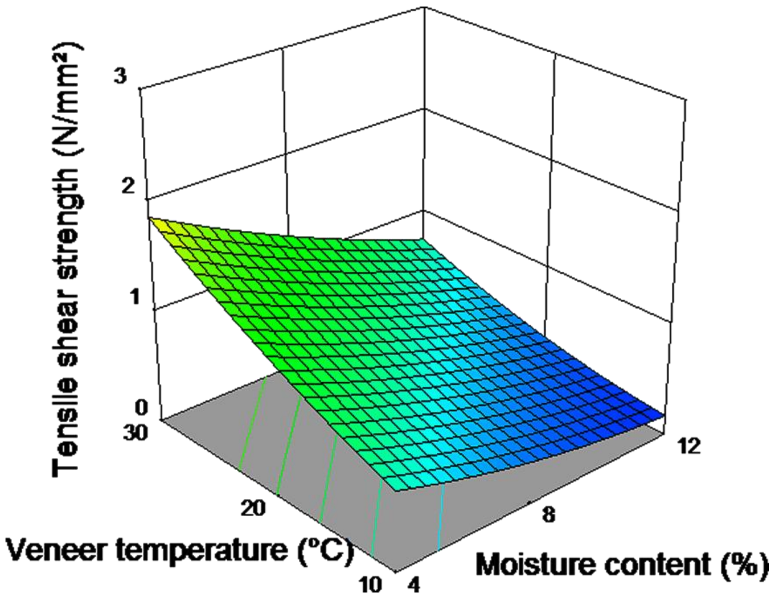

Figure 2: 3D model plot of tensile shear strength as a result of cold tack for different veneer moisture content, veneer temperature at a resin age of 1 week, a lay-up time of 30 minutes, a pre-press time of 45 minutes and a resin amount of 150 g/m²

In contrast to many studies where performance of the cured bond is in focus, cold tack is assessed by monitoring the behaviour of the resin in uncured state. Therefore, an analytical method has been developed allowing the examination of the influence of the defined factors on the cold tack. Hereby, tensile shear strength was used as main parameter to test the cold tack behaviour of the resin (HOGGER ET AL 2018a).

Samples of rotary cut sheets of birch veneer were equilibrated in a climate chamber. A mixture of an industrial UF resin for plywood application (Metadynea Austria GmbH) and ammonium chloride hardener was applied with a spatula and distributed evenly on the surface of the veneer. A second veneer was placed on the overlapping surface with no external pressure and the veneers were stored in a climate chamber for the period of the lay-up time. Following the lay-up period, the samples were pre-pressed while exposing the samples to the same controlled climatic conditions. The samples were tested subsequently in tensile shear mode using a universal testing machine (HOGGER ET AL 2018a).

Based on the data obtained, a statistical model was developed which can predict cold tack as a function of the combination of many influencing factors. For example, cold tack decreases as the wood moisture increases, or increases with increasing temperature (Figure 1). Surprisingly, there are even conditions where it makes sense to reduce the amount of adhesive applied. Thus, the production conditions in plywood production can be adjusted knowledge-based.

As a completion of the work, a selection of resinated veneers was hot pressed in order to cure the resin. It could be shown that although cold tack strongly influences the production of birch plywood, the properties of the final product are not affected (HOGGER ET AL 2018b).

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Heat transfer through the wood layers in the process of veneering of particle board in the hot presses.

Vasil Merdzhanov[1], Dimitar Angelski[2]

[1]Bulgaria, Sofia, 10 "Kl. Ochridski" blvd. University of Forestry, Assoc. professor, PhD
vasilmerdzhanov@gmail.com

[2]Bulgaria, Sofia, 10 "Kl. Ochridski" blvd. University of Forestry, Assoc. professor, PhD
d.angelski@gmail.com

Keywords: veneering, wood veneer, heat transfer, urea formaldehyde resin, veneering conditions

ABSTRACT

The quality of the veneered aggregates and the sparing use of heat require the exact dosing of the heat quantity to solidify the adhesive and the regulated set of temperature level. Different thermoreactive adhesives are cured at a specific duration and temperature of heating. Determining the optimal limits of these factors results in cost savings, high bond strength, and reduced veneering defects.

A study was conducted to determine the rate of heat transfer through the veneer sheet to reach a certain temperature level relative to a set press temperature. Veneer layers of different thickness from beechwood (Fagus sylvatica L.) are used. Three levels of temperature are studied to cover all the type adhesives actually used. Details of the materials studied and the technological parameters are presented in Table 1.

Table 1: Parameters of materials and process

beechwood Fagus S.	thickness [mm]	humidity [%]	density of veneer [kg/m^3]	temperature of the hob [^{o}C]	duration of heating [s]
series 1	0.5±1%	7+10%	634 kg/m^3 ±3%	60-100-140	300
series 2	1.0±1%	7+10%	634 kg/m^3 ±3%	60-100-140	300
series 3	1.5±1%	7+10%	634 kg/m^3 ±3%	60-100-140	300

Curing of the adhesive in hot presses is by indirect heating through the cladding layer. The type, thickness and thermal performance of this material are the main factors influencing the process. On the other hand, according to our studies [1,2], modern UFR-based adhesives have a significantly longer cure time. All experiments were carried out at a constant specific pressure of 0.2 MPa. The temperature is measured by thermocouples placed between the slab and veneer, as well as between the press and veneer.

Figure 3 illustrates the change in the temperature of the boundary chipboard - plywood, at 140^{o}C set temperature of the hob. High temperature gradient and the different thickness, do not allow for the study period to minimize the temperature difference, which remains 11^{0}C for beech veneer with a thickness of 1,5mm after 300s duration of heating.

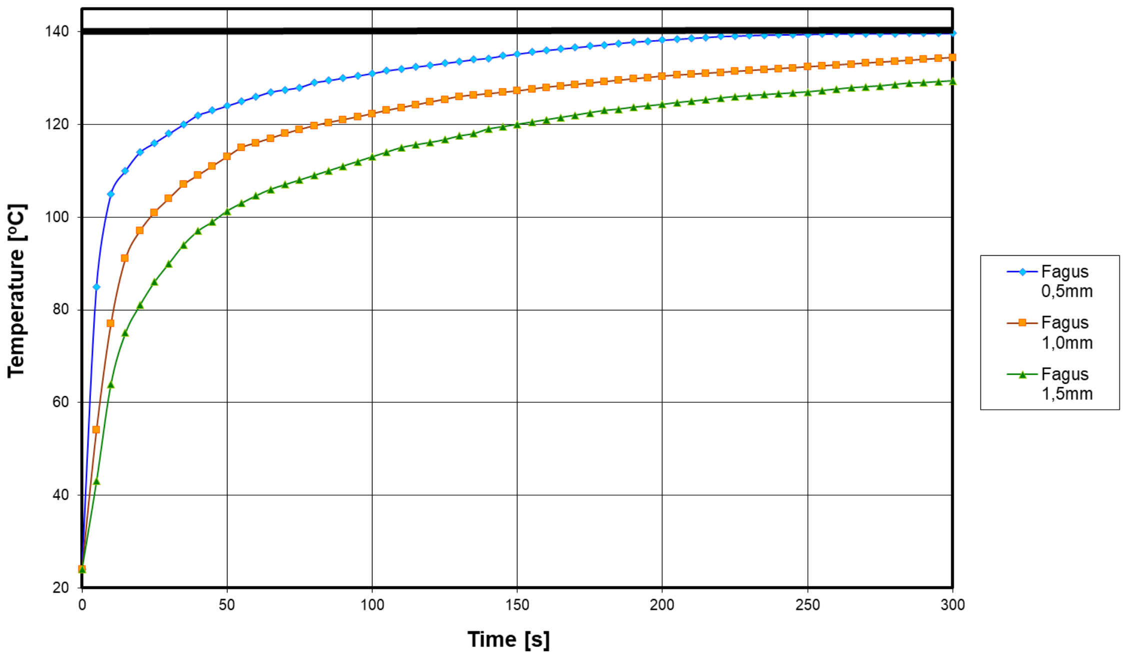

Figure 1. Change of the border temperature chipboard - veneer, at T = 140⁰C

- The influence of the thickness of the veneer layer is enhanced by increasing the temperature of the panel from 60^0C to 140^0C;
- The increase in the temperature of the 100 to 140^0C table does not lead to a proportionate shortening of the curing time of the glue, especially for veneers thicker than 1mm.

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Physical Indicators of High-Density Fibreboards (HDF) Manufactured from Wood of Hard Broadleaved Species

Julia Mihajlova [1], Viktor Savov[2]

[1] Bulgaria, University of Forestry, Sofia, e-mail: jmihajlova@ltu.bg

[2] Bulgaria, University of Forestry, Sofia, e-mail: victor_savov@ltu.bg

Keywords: physical indicators, HDF, hard broad-leaved tree species, pressing pressure, phenol-formaldehyde resin content.

ABSTRACT

To produce HDFs, wood-fibre mass from wood of beech and Turkish oak has been used. The mass has been manufactured after the Asplund method, with industrial unit “Defibrator”. The water content in the mass is 11%, and its bulk density is 30 kg.m^{-3}. The boards have been manufactured under laboratory conditions after dry method.
The summarized indicators for the physical indicators of HDFs in case of change in pressing pressure and PFR content according to the experiment plan are presented in Table 1.

Table 1: Results for the physical indicators of HDFs

No.	Pressing pressure *P*, MPa	PFR content P_x, %	Density ρ, kg.m^{-3}	Water absorption *A*, %	Swelling in thickness G_t, %
1	3.0	10	1003	30.67	15.20
2	4.0	10	1067	21.52	12.32
3	5.0	10	1116	21.31	11.45
4	3.0	12	1055	23.77	13.47
5	4.0	12	1065	20.99	13.14
6	5.0	12	1126	20.55	9.60

The density of the manufactured HDFs, in case of variation of the hot pressing pressure from 3 to 5 MPa and PFR content of 10% and 12%, varies from 1003 to 1126 kg.m^{-3}. Therefore, the boards may be classified as very hard and super hard high-density fibreboards.
Graphically, the effect of pressing pressure and PFR content on the density of the boards is presented in Fig. 1.

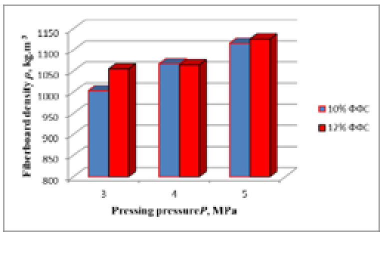

Fig. 1. Dependence of the density of HDFs on the pressing pressure and PFR content

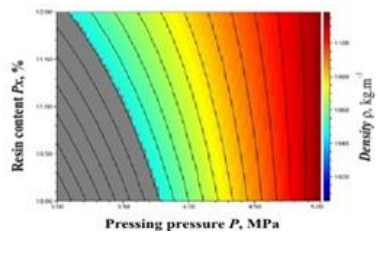

Fig. 2. Lines of constant level for density in case of super hard HDFs

In order to manufacture super hard HDFs (with density above 1050 kg.m^{-3}), the pressing pressure should be at least 3.8 MPa at 10% PFR content, Fig. 2. In the figure, the combination of the level of factors at which the respective density is not reached, i.e. very hard HDFs, and not super hard ones are manufactured, is presented with the grey area. In case of increase of PFR content up to 12%, the pressure at which super hard HDFs may be manufactured is at least 3.2 MPa.

The water absorption of HDFs in case of change in the values of the examined factors varies from 30% to 20.5%. Graphically, the relationship between the water absorption and the pressing pressure and the PFR content is presented in Fig. 3. The change in the swelling in thickness of HDFs depending on the pressing pressure and PFR content is presented graphically in Fig. 4.

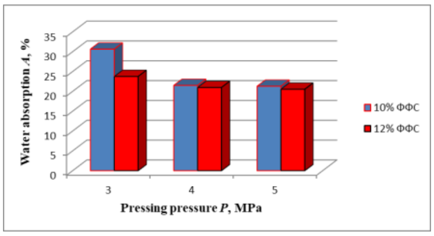

Fig. 3. Dependence of the water absorption on the pressing pressure and the PFR content

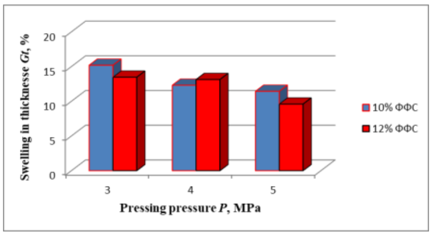

Fig. 4. Dependence of swelling in thickness of HDFs on the pressing pressure and PFR content

The swelling in thickness of FBs varies from 15.2% to 9.6%.
As a result of the performed investigation and analysis for the pressing pressure impact, within a range of 3 to 5 MPa, and 10% and 12% PFR content on the physical indicators of HDFs, the following main conclusions may be drawn:

1) In boards with 10% PFR content, uniform distribution of the density in case of increase of pressing pressure from 3 to 5 MPa is observed, with significant increase of the density being observed at a pressure of MPa with increase of PFR content from 10% to 12%;
2) The increase of the pressure from 4 to 5 MPa does not lead to significant improvement of the water absorption of HFBs;
3) All produced boards meet the requirements for the swelling in thickness indicator for general-purpose hard FBs for use in humid environment;
4) In order to meet the requirements for swelling in thickness of superhard FBs for use under external conditions at 10% PFR content, the pressing pressure should be at least 4 MPa, and at 12% PFR content, the pressure should be at least 3.7 MPa.

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Machinability of birch compared to pine and wood-plastic composites in routing

Ossi Martikka[1], Timo Kärki[1]

[1] Lappeenranta University of Technology, Skinnarilankatu 34, 53850 Lappeenranta, Finland.
ossi.martikka@lut.fi

Keywords: Machinability, tool wear, surface roughness, birch, pine, WPC, routing

ABSTRACT

Birch is an important tree species in Scandinavia and northern Europe for forest industry (Hynynen, Niemistö et al. 2009, Lilja, Thinggaard et al. 2012). Sawn birch timber is used in carpentry and especially for the furniture industry. The parquet industry also uses large amounts of sawn birch timber (Luostarinen, Verkasalo 2000). Scots pine is one of Europe's most important forest trees (Ahtikoski, Ojansuu et al. 2012) and is used as sawn timber in structural indoor and outdoor uses, joinery and interiors (roofs, walls, doors, parquets, windows), furniture, etc. (Grekin 2006).

In carpentry industry, machining is commonly used to give shape to products and preforms. Wood plastic composites are gaining markets and are used to replace timber in various applications, where machining is also applied. Machinability describes how easily material can be removed with a satisfactory finish and low cost (Black, Kohser 2011), but machinability of birch with tool-wear has not been commonly studied.

The aim of this study is to determine machinability and possible differences between the machinability of solid woods and wood-polypropylene composites (WPC) in routing.

Materials and methods

The solid wood materials tested were birch (Betula spp.) and pine (Pinus sylvestris), both harvested in Finland. The composite materials were manufactured at LUT's Fiber Composite Laboratory. Naming and the composition of the materials is presented in Table 1. Machinability was determined by measuring tool wear and change in surface roughness (Ra).

Table 1. Tested materials. 'Comp' denotes composite material.

Material code	Wood content [%]	Wood species or type	PP content [%]	PP type	Lubricant content [%]	Additive type & content
Birch	100	Birch	N/A	N/A	N/A	N/A
Pine	100	Pine	N/A	N/A	N/A	N/A
Comp 1	75	Spruce	22	Virgin	0	None
Comp 2	69	Wood pellet	25	Recycled	2	Color, 1%

A CNC-machining center was used in the tests. A single flute, replaceable insert straight cutter was the cutting tool used. The inserts have a tungsten carbide body, are titanium nitrate coated, and are designed for machining of solid wood and wood-based panels (e.g. HDF and MDF). For each cutting blade, 115.5 meters of routing was performed on each material, and the evolution of surface roughness and tool wear were measured.

Results

Results show (Figure 1), that birch timber caused least wear to the tool, and the change in the surface roughness during tests was insignificant. With pine, the tool wear was marginally higher than with birch, and the final surface roughness was slightly higher. Composite 1 had similar surface roughness with pine, but wear on tool was the highest of the tested materials by margin. The greatest change in surface roughness was found with composite material 2: 26%. Based on the findings, the type of wood material has notable influence on the machinability of both solid wood and wood-plastic composites.

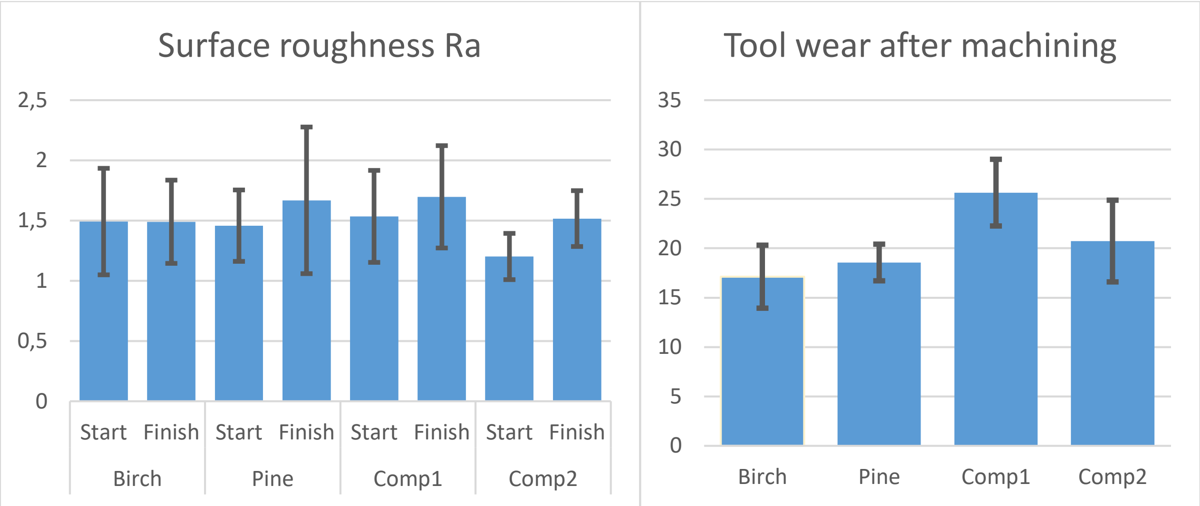

Figure 1. Change in surface roughness and tool wear in machining.

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Parallel Session VII.
Surface coating and bonding characteristics of hardwoods

Surface quality and adherence of thermally compressed and finished birch wood

Pavlo Bekhta[1], Tomasz Krystofiak[2]

[1] Ukrainian National Forestry University, Department of Wood-Based Composites, Cellulose and Paper, Gen. Chuprynky 103, 79057 Lviv, Ukraine, E-mail: bekhta@ukr.net

[2] Poznan University of Life Sciences, Department of Gluing and Finishing of Wood, 60637 Poznan, Poland, E-mail: tomkrys@up.poznan.pl

Keywords: adhesion strength; birch veneer; surface gloss; thermal compression; varnish; wood substrate

ABSTRACT

Wood surfaces are typically sanded before the lacquer coatings technological processes. Our previous works (BEKHTA ET AL. 2014a, 2014b) showed that short-term thermo-mechanical densification improves attractiveness of wood surface. Such densified wood is characterized by an attractive darker colour and high gloss. This facilitates the application of transparent organic coatings that allow improving the natural characteristics of wood to remain it visible, and so the demand for them has been increasing.

This article discusses the aesthetic properties and adherence of lacquer coatings formed on medium density fibreboard (MDF) panels, veneered with thermally compressed birch wood. The effect of thermal compression temperature, veneer side (loose vs. tight), the number of lacquer layers and spread rates on the gloss and adhesion strength of lacquer coatings were determined. Rotary-cut birch veneer sheets were thermally compressed at various temperatures (150, 180 and 210 °C) and afterwards they were bonded to the surfaces of MDF panels. The lacquer was applied to the surface of veneered MDF panels in 1, 2 and 3 layers at the various spread rates, appropriate 50, 75 and 100 g/m^2. Gloss was determined acc. to the DIN 67530 and ISO 2813 standards using a PICO GLOSS 503 photoelectric apparatus. The adhesion was assessed using the pull-off test.

Statistical analysis showed, that the number of layers, the amount of lacquer, the direction of wood fibres, the side of veneer and compression temperature significantly affect gloss of the surfaces of veneered MDF panels. Gloss increased with the number of layers and the amount of applied lacquer. Brightness decreases with the increase in temperature from 150 to 180 °C, while a further increase in temperature from 180 to 210 °C enhances gloss.

Statistical evaluation of adhesion showed, that among studied variables the compression temperature significantly affects adhesion strength. The highest adhesive strength is observed for samples compressed at the temperature of 180 °C. The number of layers does not affect the adhesion between varnish and thermally compressed substrate. Thermal compression of wood substrate homogenises the surface and as a result the loose and tight sides of the samples did not make any significant differences in their gloss and adhesion strength values.

The preliminary findings obtained in this study indicated that replacing the sanding process with thermal compression of wood veneer surface before coating could be considered as an alternative method of producing coated MDF panels with satisfactory aesthetic and adhesion strength properties and reducing lacquer product consumption. The thermally densified surface plays the function of primers and the lacquer product is less absorbed by the substrate. Moreover, a significant reduction of varnish consumption reduces the emission of harmful substances into the environment and further facilitates the recycling of such coated products.

Consequently, the use of thermally densified veneer in coating processes in addition to economic advantages will also have environmental benefits.

ACKNOWLEDGEMENT

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Glossiness of coated alder wood after artificial aging

Emilia-Adela Salca[1], Tomasz Krystofiak[2], Barbara Lis[2]

[1]Transilvania University, Eroilor 29, 500036, Brasov, Romania, email:emilia.salca@unitbv.ro

[2]Poznan University of Life Sceinecs, Woska Polskiego 28, 60-637, Poznan, Poland,

emails: tomkrys@up.poznan.pl; blis@up.poznan.pl

Keywords: aging, alder, coating, glossiness, varnish.

ABSTRACT

This study reports the changes in glossiness of wood coated surfaces after artificial aging. Boards made of black alder wood were purchased from a local sawmill in Romania and planed samples were produced. They were subjected to parallel sanding by using two grit size sandpapers such as 100 and 150, respectively. The samples were coated by spraying under laboratory conditions at Remmers Company in Poland. Two varnish types were used: a UV and a water-borne (WB) varnish, respectively. In each case two varnish layers were applied with a light sanding of 220 grit size sandpaper prior to the second coating layer. The coated samples were cured under different conditions according to their type. Thus, a UV unit was used for the curing process in case of UV coated samples, while the samples coated with WB varnish were cured under laboratory conditions. For the intensive artificial UV+IR aging of coated specimens, a special quartz lamp of VT-800 type having 740W radiation energy was used (Fig. 1). The samples were subjected to radiation for one, two and four hours span time. The surface glossiness of the coated samples was measured both parallel (II) and perpendicularly (≠) to the wood grain before and after aging by employing the Pico Gloss 503 meter. The variation of surface glossiness at 60° geometry as a function of varnish type and exposure time to artificial aging is presented in Fig. 2.

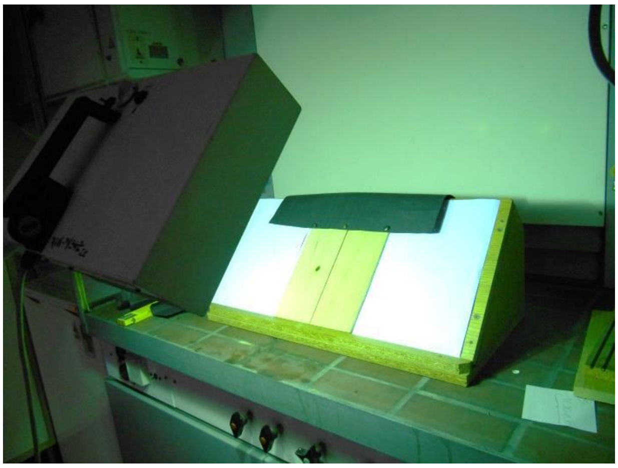

Figure 1: The quartz lamp of VT-800 type and samples under exposure

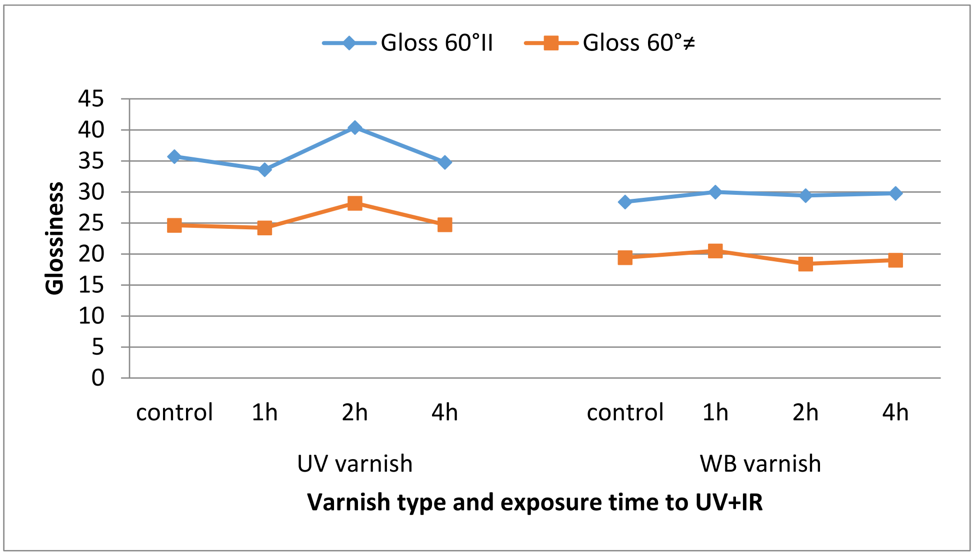

Figure 2: Variation of glossiness as a function of varnish type and exposure time to artificial aging

The two varnishes produced specific and different glossiness levels based on their structural differences. In case of UV varnish the coating structure is more cured producing a higher gloss level due to the influence of UV energy when compared to water-borne varnish type (SALCA ET AL. 2016). As expected, the results of this work indicate that the artificial aging influenced the gloss of the coating layer. Small variations of the glossiness values after aging were noticed in case of coated samples with water-borne varnish. In case of UV varnish the gloss variation after aging recorded up and down trends. Similar findings have been reported in the specialty literature (DEMIRCI ET AL. 2013, PELIT ET AL. 2015, AYATA ET AL. 2018).

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Improvement of ash (*Fraxinus Excelsior* L.) bonding quality with one component polyurethane adhesive and hydrophilic primer for load bearing application

Peter Niemz[1], Gaspard Clerc[1], Joseph Gabriel[2], Dario Salzgeber[2], Thomas Strahm[3] Frederic Pichelin[1],

[1]Bern University of Applied Sciences,

Solothurnstrasse 102 CH 2500 Biel, Switzerland

[2]Henkel & Cie. AG Industriestrasse 17a CH-6203 Sempach Station

[3] neue Holzbau AG Obseestrasse 11CH-6078 Lungern

* *E-Mail address:* peter.nimz@bfh.ch

Keywords:

ABSTRACT

The increasing quantity of hardwood growing in the Swiss forest represents an opportunity for the future of the wood industry. Glued laminated timber made of hardwood offer higher strength and stiffness properties than their equivalent in softwood, they are often used in combination with softwood for local reinforcement. Also, their visual aspect can be an attractive selling argument. Nowadays, only phenol resorcinol adhesive (PRF, Aerodux 185) are able to provide a constant bonding quality concerning ash wood gluing. Despite their high bonding performance, these adhesives have several disadvantage such as a dark brown glue line and a strong emission of formaldehyde during the gluing. One component polyurethane (1C-PUR) adhesives, widely used in load bearing structure made of softwood represent an interesting alternative. These adhesives require no mixture and present an invisible glue line without any formaldehyde emission. Preliminaries experiment showed that the combination of slow reacting 1C-PUR adhesive with a water based Primer system obtained similar results as the Aerodux 185 in laboratory conditions. This paper focuses on the optimization of the gluing process of two different 1C-PUR adhesives with ash wood to develop an industrial application process. The influence of several factors such as primer concentration, primer quantity was investigated using delamination test according to DIN EN 302-2.

It was shown that it is possible with 1C-PUR to reach the normative standard according to DIN EN 15425. The best results were obtained with a primer concentration of 10 % and a primer-water applied quantity of 20 g/m^2. The influence of the primer open time was shown to have only small effect. 1C-PUR with a long closed assembly time were shown to perform better. Also the reduction of the lamella thickness was shown to reduce the delamination. By taking those parameters into consideration it was possible to develop an industrial process allowing to produce high performance glued laminated timber out of Ashwood and glued with 1C-PUR adhesive. Fig 1 show selected results

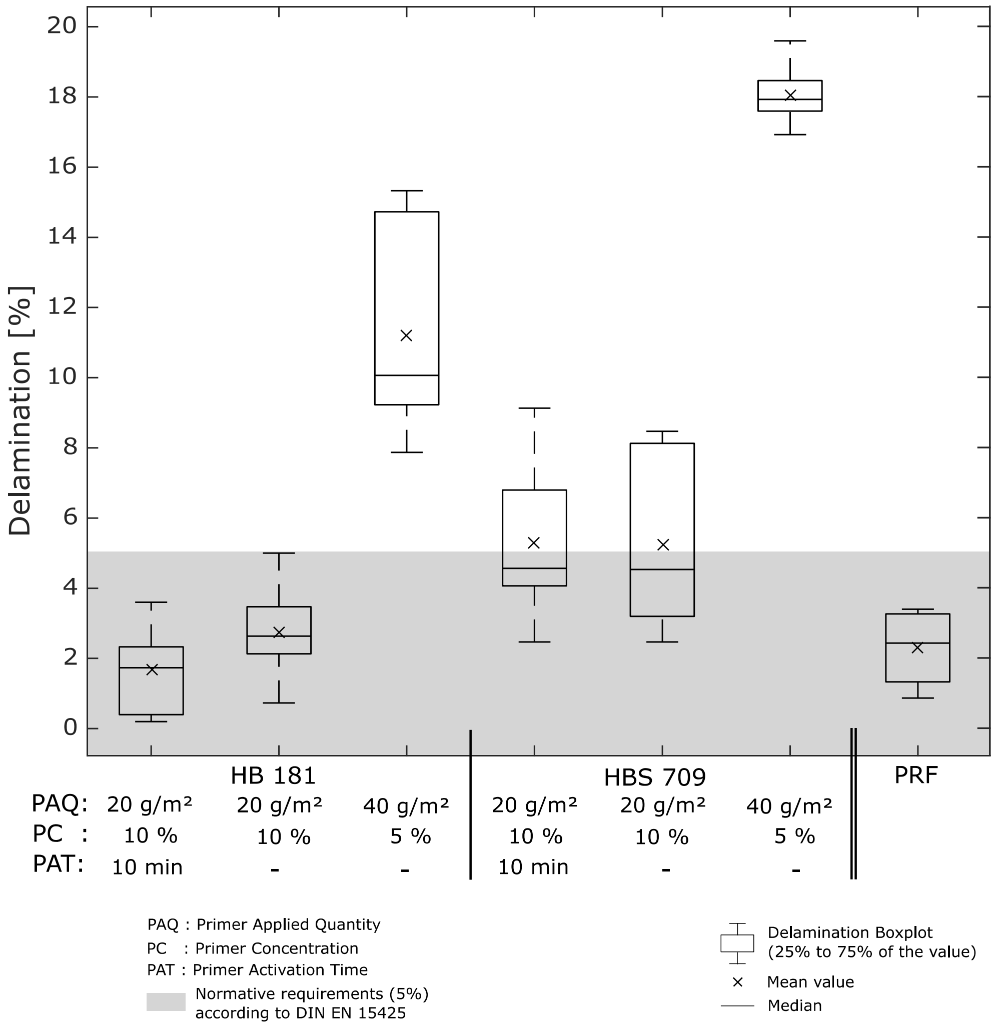

Figure 1: Delamination results with variable primer application (PAQ), primer concentration (PC) primer activation time ***(PAT) 2 for the adhesives HB S709, HB 181 (Henkel) and PRF (Dynea)***

Structural hardwood bonding and the impact of wood accessory compounds

Stefan Bockel[1,3], Steffen Harling[2], Johannes Konnerth[3], Peter Niemz[1], Frédéric Pichelin[1]

[1] Bern University of Applied Sciences, Solothurnstr. 102, Switzerland, stefan.bockel@bfh.ch, peter.niemz@bfh.ch, frederic.pichelin@bfh.ch

[2] Collano AG, Neulandstr. 3, Switzerland, steffen.harling@collano.com

[3] University of Natural Resources and Life Sciences, Konrad-Lorenz-Str. 24, johannes.konnerth@boku.ac.at

Keywords: wood extractives, structural adhesives, interface, rheology, lap-shear

ABSTRACT

The bonding of hardwood for structural applications challenges science and industry. Beside the special physical and mechanical properties of hardwood, the chemical composition e.g. wood extractives are expected to influence the bond performance primarily at the interface area (compare Figure 1). Subject of this study is to determine which extractive influences the adhesive and if their origin in soft- or hardwood can be related to the adhesives performance.

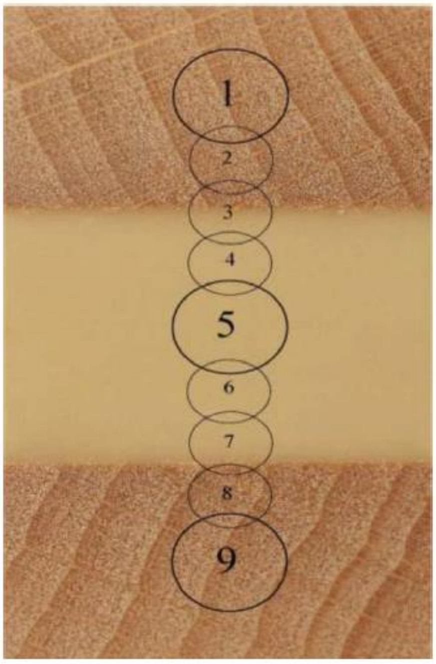

Figure 3 Model of wood bonding representing the bulk material (1, 5, 9), interface (3,7) and the interphase region (2, 4, 6 and 8) according to Marra et al. (1980)

Therefore, seven different wood extractives namely pentanal, 3-carene, limonene, starch, gallic acid, linoleic acid and acetic acid were used in this study as well two structural adhesive systems such as two-component polyurethane (2C PUR) and melamine-urea formaldehyde (MUF). The influence of extractives on the rheological behaviour was tested in terms of gel point and storage modulus. Furthermore, extractives were artificially applied on freshly planed beech wood

(*Fagus sylvatica* L.) and afterwards bonded and tested in tensile shear mode. The ratio of extractive to applied adhesive obtained 10% on wet weight of the adhesive.
In the rheological experiments, acetic acid reduced the gel point for 2C PUR and the storage modulus was lowered by pentanal and acetic acid. For MUF, acetic acid reduced the storage modulus but did not accelerate the gelation. Beech wood joints tested in lap-shear mode revealed a negative influence in tensile shear strength for acetic acid with 2C PUR. MUF and starch showed a reduction in tensile strength in dry and wet conditions. From these experiments it can be concluded that both structural adhesives are sensitive to some extractives when latter occurs surface-wide and in high concentrations. Regarding the origin of these extractives it can be briefed that extractives which occur in soft- and hardwoods have a higher influence on the adhesives than extractives which are common for each type.

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Adhesives for Fast Heated Bondlines in Structural Timber-Concrete-Composite Joints

Malte Mérono[1], Carola Link[1], Gregor Wisner[2], Elisabeth Stammen[2], Klaus Dilger[2], Artur Ginz[3] and Werner Seim[3]

[1] Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut WKI, Bienroder Weg 54E, 38108 Braunschweig, Germany, malte.merono@wki.fraunhofer.de

[2] IFS – Institute of Joining and Welding, Technische Universität Braunschweig, Langer Kamp 8,

38106 Braunschweig, Germany, g.wisner@tu-braunschweig.de

[3] University of Kassel, Department of Timber Structures and Building Rehabilitation, Kurt-Wolters-Straße 3, 34125 Kassel, Germany, aginz@uni-kassel.de

Keywords: composite element, timber-concrete-composite, bonding, adhesive tape

ABSTRACT

In the building industry, different construction materials and building processes are well established worldwide. New combinations of different materials like timber-concrete-composites can bring benefits regarding lightweight design, increased prefabrication and faster building to increase productivity (EISENHUT et al. 2016).
A new approach regarding the usage of specific adhesive tapes between both, the prefabricated timber and the concrete part allows a fast curing by applying high temperatures in the bondline (WISNER et al. 2015). The adhesive tape is based on an adhesively coated metallic carrier (Fig. 1). The ends of the tapes are connected to an electric power supply similar to a welding workstation for controlled conductive resistive heating (Fig. 2).

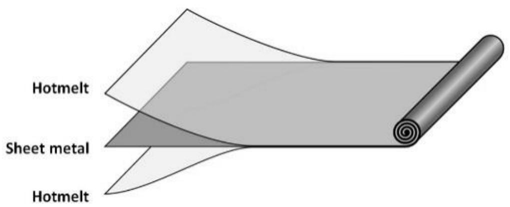

Figure 1. Structure of a pre-coated electric heatable composite adhesive tape (© Fraunhofer WKI)

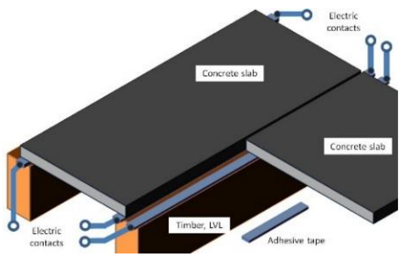

Figure 2. Timber-concrete joints by electrical heated adhesive tapes (© IFS-TU-Braunschweig)

The adhesives have to fulfil a number of boundary conditions derived out of the different substrates (timber from beech and spruce, standard to high performing concrete) and should be able to cure at high heating rates by electrical heated thin metal carriers in the bondline (WISNER et al. 2014). This is a very good precondition for a highly productive joining on the construction site.
Investigations in a research project in Germany started with a screening for most appropriate adhesives in a broad range of polymer chemistry (Epoxy-, Polyurethane-, Phenolic-based and Co-Polyamides). To evaluate the performance of up to 12 different adhesives, block-shear-strength tests acc. to EN 14080 (mechanical properties) and additional DSC (differential scanning calorimetry for hot-curing capability) experiments were carried out. The 12 adhesives were tested in the hot-curing process. Phenol-Resorcin, 2 part EP, 2 part PUR and 1 part PUR were tested in cold-curing process too, for reference benchmarks. For every adhesive and wood-type (beech and spruce) three beams of sand blasted concrete (C45/55) and timber were

adhesively joined. From each beam five specimens (25 x 25 x 100 mm) were cut for testing acc. EN 14080. The temperature for hot-curing ranged between 170 - 230 °C and was hold for 300 s or 600 s. After the first section, four adhesives (Phenol-Resorcin, 2 part EP for cold-curing as a reference group and 2 part EP, Co-Polyamid and 1 part-EP for hot-curing) were chosen for further investigation.
In the second part of the screening, different formwork surfaces from concrete were tested to define, if this kind of surfaces can be used in addition to sandblasted ones. The test-procedure was identically like in part one and was carried out by the above named four adhesives. Therefore concrete specimen manufactured by three different formwork materials (faced Poplar-Plywood, film-faced Particleboard and steel formwork) were examined.
By analysing the cold curing process, it could be seen that sand blasted surfaces are significantly better or even as good as formwork surfaces by using beech wood. In all cases the reference group fulfil the requirements of block-shear-strength for single bondlines of the EN 14080 (6.0 N/mm²), except for specimens casted in steel formwork (Fig. 3).
In the case of the hot-curing process, only the specimen produced with faced Plywood and film-faced Particleboard fulfil the requirements for beech wood. The sand blasted surface showed a high roughness (> 2 mm) and led to an inhomogeneous heat distribution in the bondline. That influences the strength of the bondline in a negative way (Fig. 4).
Furthermore, it could be demonstrated that formwork surfaces made of steel lead to lower block-shear strength and adhesive failure (AF) in general, which might was caused by remains of release agents. The results for spruce are comparable to the results of beech wood.

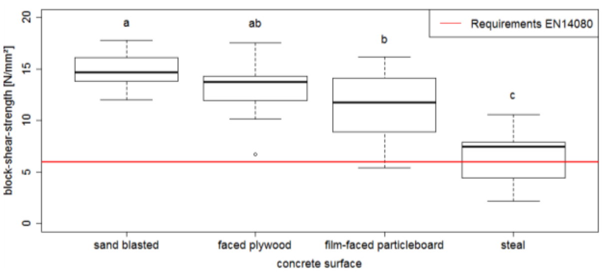

Figure 3. Block-shear-strength acc. to EN 14080 on beech wood for cold-curing process

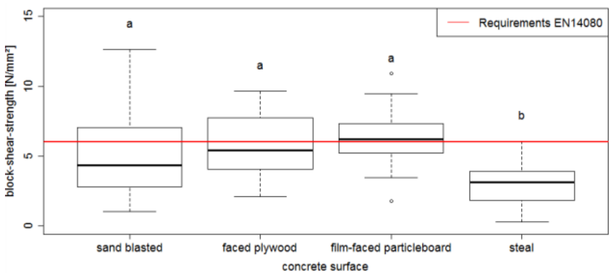

Figure 4. Block-shear-strength acc. to EN 14080 on beech wood for hot-curing process

For the next step specimen with the dimension of 300 x 50 x 50 mm will be tested with the above-named adhesives for their short-term behaviour. In addition, long duration tests for bending and creep deformation in accordance to EN 408 and EN 302-8 will be conducted over the next 12 months to test and evaluate the long-term behaviour.

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Birch for engineered timber products

David Obernosterer[1], Georg Jeitler[2], Manfred Augustin[3]

[1] Sachsenburg/Austria, HASSLACHER NORICA TIMBER, david.obernosterer@hasslacher.com

[2] Sachsenburg/Austria, HASSLACHER NORICA TIMBER, georg.jeitler@hasslacher.com

[3] Graz/Austria, holz.bau forschungs gmbh, manfred.augustin@tugraz.at

Keywords: birch, hardwood, glued laminated timber GLT, combined GLT, laminated veneer lumber LVL

ABSTRACT

HASSLACHER NORICA TIMBER is a wood processing company with more than 1.600 employees and plants in Austria, Slovenia, Germany and Russia. In the forests around their Russian sawmill the wood species birch (Betula pendula) is growing in large quantities and cut-able qualities. Consequently the idea was born to develop load-carrying GLT (and CLT) made from birch to be able to use the available resources as well as to create products with far better mechanical properties. Therefore, a series of three projects was started to check the possibility of production of glued laminated timber made from birch, of birch-LVL (laminated veneer lumber) and of hybrid-GLT-beams made from spruce and birch wood. The last project regarding the hybrid-glulam will be a doctoral thesis starting in July 2018.

Introduction

Birch (Betula pendula), which is one of the main wood species in the forests near St. Petersburg in Russia, is currently almost not used for structural applications. The idea of the first project was to check the possibility of application for this wood species utilising in the field of engineered wood products like glued laminated timber (GLT) as well as cross laminated timber (CLT) for load-carrying purposes. The biggest part of the project was done on the development of a complete mechanical profile of the wooden products. The corresponding tests were done in close cooperation with the holz.bau forschungs gmbh, a competence centre at Graz University of Technology. Additionally, to improve the design values of the final products, a bachelor thesis was done focusing on the possibility to use birch wood as laminated veneer lumber (LVL). The thesis further compared the values from the birch GLT project with the ones from the product “BauBuche” (company Pollmeier / Germany) and the results of the birch LVL testing, which was done at the Institute of Wood Technology and Renewable Materials at the University of Natural Resources and Life Sciences.

Test material and methods

The raw material for the tests was cut and kiln-dried to a moisture content of about u = 12% at the Russian saw mill of the Hasslacher group HasslacherLes in Malaya Vishera. After the transport of the boards to the production plant in Austria the material was stress graded by means of a device using the dynamic modulus of elasticity (GoldenEye 706 from Microtec®) and in addition visually graded acc. to the rules of DIN 4074-5 strength class LS10+, i.e. boards with properties fulfilling the requirements of grading class LS13 remained in the tested material. A number of 40 boards were sawn into veneers, shuffled and glued together again as birch LVL. The adhesive used for finger joints, GLT and LVL was a two-component melamine-urea-formaldehyde (MUF) adhesive system.

Results

The following table shows selected results of the tested samples. The results for the boards, finger joints and GLT made from birch can be found in the report of AUGUSTIN AND SIEDER (2015) and was presented by JEITLER ET AL. at the WCTE 2016 in Vienna. The complete profile of mechanical properties for birch GLT is also published by SCHICKHOFER (2015). The research about the birch LVL was done by OBERNOSTERER (2015).

Table 1: Mechanical properties and density

		Birch boards	Finger joints	Birch GLT	Birch LVL
Bending strength	$f_{m,k}$	-	60,4 N/mm²	32 N/mm²	66 N/mm²
Shear strength	$f_{v,k}$	-	-	4,5 N/mm²	6,3 N/mm²
Tensile strength	$f_{t,0,k}$	24,4 N/mm²	43,9 N/mm²	26 N/mm²	-
Compressive strength	$f_{c,90,k}$	-	-	4,5 N/mm²	-
Modulus of elasticity	$E_{0,mean}$	14.300 N/mm²	-	15.000 N/mm²	17.500 N/mm²
Density	ρ_k	547 kg/m³	550 kg/m³	600 kg/m³	660 kg/m³
	ρ_{mean}	597 kg/m³	610 kg/m³	620 kg/m³	680 kg/m³

The results of the performed mechanical testing have shown high performance of birch in structural use. Especially the LVL made from birch has strongly increased bending strength compared to GLT due to the homogenisation effect. Because of the excellent results, in a next step a doctoral thesis will deal with hybrid GLT made from spruce boards and birch boards and LVL. This project is to be started in July 2018 in cooperation with the Institute of Timber Engineering and Wood Technology in Graz.

Figure 1: Pilot project in Carinthia made with birch GLT, industrial hall covering 1,000 m² with largest free span of 27 m and a maximum cross-section of the main girder of 100x1000 mm

ACKNOWLEDGEMENT

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Parallel Session VIII.
Hardwood in construction

Mechanical Properties Estimation by Non-destructive Testing of Irish Hardwood Round Timber from Thinnings for Construction Purposes

Daniel F. Llana[1], Ian Short[2], Conan O'Ceallaigh[3], Annette M. Harte[4]

[1,3,4] Timber Engineering Research Group and Ryan Institute, National University of Ireland Galway, Ireland, [1]daniel.llana@nuigalway.ie, [3]conan.oceallaigh@nuigalway.ie, [4]annette.harte@nuigalway.ie

[2] Forestry Development Department, Teagasc, Ashtown, Dublin, Ireland, ian.short@teagasc.ie

Keywords: hardwood thinning, non-destructive testing (NDT), small round timber

ABSTRACT

Thinning involves the removal of competitors of high quality trees, and trees for extraction racks, all to favour the growth of the selected trees. Many felled trees are small-diameter and in Ireland hardwood thinnings are mainly used for energy production (DORAN 2012; MOCKLER 2013) or for wood-based panels or in the pulp industry (CAMPION AND SHORT 2016). Since the 1990's the Irish Government has been encouraging private owners to combine agricultural and forest commercial activities. Grant aid was initially provided each year for the first 20 years (nowadays 15) in order to compensate the loss of agricultural land use. Furthermore, the first and second hardwood thinning is also grant aided. There is commercial value in seeking to use hardwood thinnings in higher value-added end uses as structural components within the construction industry and to develop its volume use in local rural industry (WOLFE AND MOSELEY 2000; CUMBO ET AL. 2004; GORMAN ET AL. 2016). The Exploitation And Realisation of Thinnings from Hardwoods (EARTH) project aims to investigate potential added-value uses of hardwood thinnings and develop a grading system for sorting into different classes, estimating mechanical properties using non-destructive testing (NDT).

Materials and methods

38 first and second thinning trees and round timber obtained from four Irish hardwood species (common alder, European ash, European birch and sycamore) were used. Time-of-flight (ToF) of acoustic waves over a 1 m length using Treesonic (Fakopp, Sopron, Hungary) device was measured on standing trees before felling. One log from the bottom part of the tree with a length 25 times its diameter was selected from each tree. According to some authors there are differences in static (MOE) and dynamic (Edyn) modulus of elasticity between bottom and top logs from the same tree (KRAJNC ET AL. 2016). The minimum diameter of selected logs was 8 cm. MTG (Brookhuis, Enschede, The Netherlands) was used to determine fundamental frequency in longitudinal direction on felled selected logs just after harvesting. After conditioning the roundwood at 65% relative humidity and 20°C, testing in four-point bending over a span of 18 times its diameter.

Results and discussion

Mechanical properties (bending strength, MOE and density) were determined in logs in order to characterize small round timber from thinnings for construction purposes. Regression models were developed to investigate the correlation between velocities obtained in standing trees and green selected logs from NDT (ToF and natural frequency) and mechanical properties obtained in conditioned logs by mechanical testing. In the regression models between acoustic velocity obtained by ToF on standing trees and mechanical properties, good correlation was found with MOE as other authors found in black poplar (CASADO ET AL. 2013). As result ToF

measurements could be considered a good method to segregate standing trees before felling them. Better correlation was found between acoustic velocity obtained in green selected logs by the resonance method and MOE as other authors showed in previous research (SANTACLARA AND MERLO 2011).

Conclusions

Non-destructive testing measurements on standing trees and green logs are suitable methods to estimate the mechanical properties of the final product, in this study round hardwood timber. Good correlation between acoustic velocity obtained in standing trees from ToF using stress waves and mechanical properties was found. Better correlation between velocity obtained from natural frequency in green logs using a resonance device and mechanical properties was found. It is possible to develop a grading system based on NDT measurements for sorting hardwood thinnings into different end-use classes.

ACKNOWLEDGEMENTS

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Mechanical evaluation of French oak timber for use in construction: relation between origin of logs, properties of boards and behaviour of glued laminated products

Guillaume Legrand, Didier Reuling, Jean-Denis Lanvin, Morgan Vuillermoz, Carol Faye

Institut technologique FCBA Allée de Boutaut, BP 227, 33028 Bordeaux CEDEX, France

Keywords: Oak, visual grading, glued laminated timber, construction

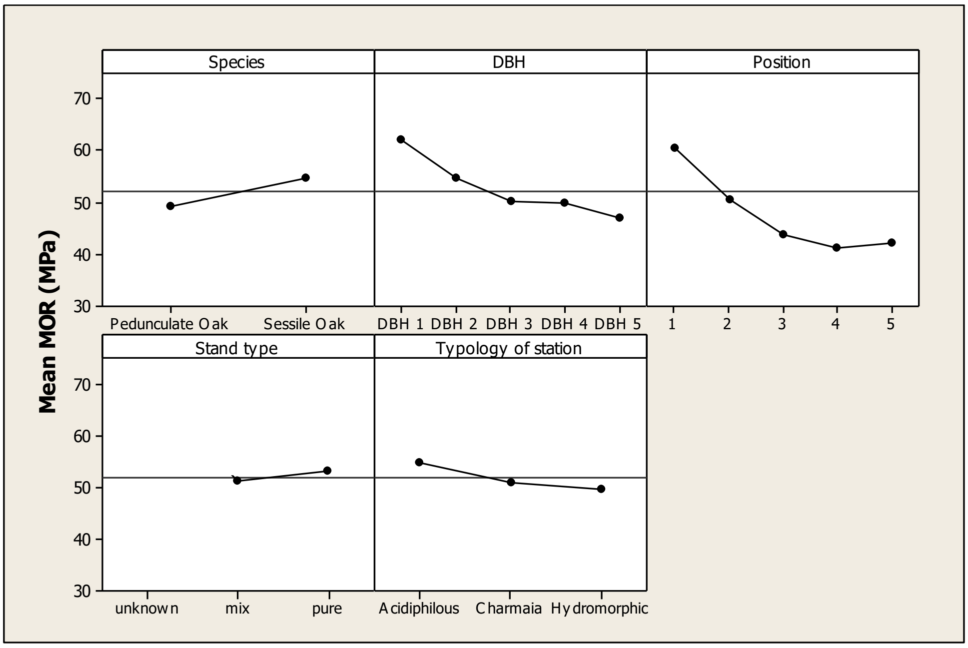
ABSTRACT

By comparison with softwood species, hardwood species are of little use in the construction sector, although the available resource is important. For example, in France and Germany, standing stocks are 898 million m^3 (Mm^3) of Beech, 1 057 Mm^3 of Oak, 173 Mm^3 of Ash and 134 Mm^3 of sweet Chestnut. For comparison, in these two countries, the softwood resource is 1 618 Mm^3 of Norway spruce, 1 049 Mm^3 of Pines and 185 Mm^3 of Douglas fir (EU-Hardwood 2014 - 2016).

The structural use of a species requires first to establish a visual grading for strength of the sawn timber allowing assignation to a strength grade according to EN 338 and then CE marking according to EN 14080-1. In the case of French oak (*Quercus robur and Quercus petraea*), the poor correlation between singularities and mechanical performances does not allow the resource to be sorted efficiently by means of visual grading (26% in D30 - Grade 1, 21% in D24 - Grade 2 and 28% in D18 - Grade 3), while the optimal grading based on destructive bending tests identifies 71% of the population in strength grades higher than D30 (Caractérisation du chêne sessile et pédonculé de France en vue de son utilisation en structure 2009 – 2011).

In order to improve visual grading performance, a predicting model according to forest and harvest parameters was developed to identify logs with the best potential for use in construction, independently of all visual criteria, but according to the diameter of the tree at 1,3 m (Diameter Breast Height: DBH) and the position (height) of the sampling along the tree. It can be seen (Fig. 1) that performance is falling with increasing DBH and sampling height along the tree, i.e. the best sawn timber comes from middle-aged trees, processed from the first log.

Pre – sorting of logs would have the advantage of eliminating logs (or log positions) that are not of interest for the construction markets. As part of the establishment of a supply chain for these markets, sawmills should therefore favor a supply of middle-aged trees, with a DBH between 25 cm and 40 cm, processed from the first log.



keys:

Diameter Breast Height (DBH):
DBH 1: 25-40 cm
DBH 2: 40-50 cm
DBH 3: 50-60 cm
DBH 4: 60-70 cm
DBH 5 > 70 cm

Position (height) of the sampling along the tree, in steps of 3.3 m:
H1 = 3.3 m
H2 = 6.6 m
H3 = 9.9 m
H4 = 13.2 m

Figure 1: Main forest and harvest parameters effects on the mean bending strength (Mean MOR) of French Oak timber

This was verified through two prototype productions of GLT made of Oak involving two different scenarios of timber supply with a low degree of change for the first one (traditional supply) and a strong degree of change for the second one (specific supply). The traditional supply was based on square edged timber traditionally proposed by Oak sawmills and usually processed from old and large diameter logs, excluding butt logs valorized on specific markets, whereas the specific supply was based on middle-aged trees (less than 80 years old) with a DBH between 25 cm and 40 cm coming from a thinning cut. Conclusions open new doors of valorization for the GLT manufacturers. Especially, the use of sawn timber issued from a selected resource (specific supply) made it possible to overcome the limiting character of the modulus of elasticity of the traditional sawn timber coming from large logs. The obstacle to a grading of the GLT at least comparable to that of softwood GLT of similar composition would then be overcome. Interesting prospects for the creation of new grades of higher characteristics are even conceivable. From homogeneous resource in the forest in terms of origin and age, it is also possible to generate a mix of sawn timber qualities which can be transformed using the entire mechanical pallet (from D18 to D40) to generate homogeneous and, above all, combined beams, mobilizing only a partial volume of high performance laminations (D30 or even D40) and using, in addition, the laminations with lower properties (D24 or even D18).

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Mechanical characterization of French hardwood species for their integration in Eurocodes 5

Thibault Benistand[1], Laurent Bleron[1], Jean-françois Bocquet[1]

[1] LERMAB – 27 Rue Philippe SEGUIN – 88000 EPINAL – FRANCE,

thibault.benistand@univ-lorraine.fr

Keywords: Hardwood, Mechanical test, EN 408, Embedding strength, dowel fastener.

ABSTRACT

France has the biggest hardwood forest in Europe with more than 1200 million of m^3 of Oak, Beech, Poplar and Chestnut (FCBA 2017). However, currently, the field of wood construction uses mainly softwood. That's why, the rise of timber construction and wood energy implies a lack of softwood resource in the next few years. That's the reason why the main actors of the wood network have to think about promoting hardwood as an alternative to softwood.
Eurocodes and other European standards are based on experiments and research realised on softwood during the last 30 years. For a better use of hardwood in the construction, the same studies must be produced in order to redefine calculation parameters specific to hardwood. The study EFEUR 5 (Comportements structurels des Essences de bois Feuillus français en vue de leur meilleure intégration aux EURocodes 5) is based on the three main hardwood species present in France with the best potential (Oak, Beech & Poplar). The two targets in this project are:

- The appreciation of the secondary mechanical properties (parallel, perpendicular and axial tension and compression strength, shear strength and modulus…) and the relation between these attributes according to EN 384 (2016).
- The embedment strength of hardwood and the calculation models for dowel-type fasteners (stiffness and plastic strength).

The first task involves validating the mechanical relationship as defined by the EN 384. In this standard, with 3 main mechanical properties (Bending strength, density and modulus of elasticity in bending) it could be possible to describe all the other mechanical properties (perpendicular or axial tension and compression strength, shear strength and modulus…). The different evolutions of this standard during last years are based on softwood research studies and the changes for hardwood are mainly based on the correlations found for softwood.
Results and conclusions presented in this paper are based on 546 bending tests, 184 compression tests parallel to grain and 184 compression tests perpendicular to grain. Tests are made according to EN 408 (2012) standard and analysed in accordance with EN 384 and EN 14358 (2016):

- There is no difference of mechanical properties between high quality woods and slightly lesser woods if the defects are rejected according to visual grading standard NF B 52-001.
- The bending strength reduces if the height of the piece of wood increases differently from the relation defined in the Eurocodes 5. A new relation based on a standard height of 200 mm could be proposed :

$$f_{m,h=200} = \frac{f_{m,h<200}}{k_h} \quad \text{with } k_h = \min\begin{cases} \left(\frac{200}{h}\right)^{0.50} \\ 1,4 \end{cases}$$

- A new relation between compression strength parallel to grain and bending strength could be proposed, $f_{c,0,k} = 4.75\ f_{m,k}^{0.5}$, and allows a gain of 10% in comparison to current relation.
- The relation between density and compression strength perpendicular to grain is confirmed for hardwood with density lower that 700 kg/m3.

An additional test program of compression parallel to grain was made in order to define the impact of moisture content on the mechanical properties:

- The current correction of compression strength of 3% per % of raise of moisture content described in EN 384 is not enough restrictive and could be replaced by this relation : $f_{c,0,12\%} = f_{c,0,i\%}\ (1 - 0{,}073\ (H_i - H_{12\%}))$
- The modulus of elasticity in compression is reduced by 1.88% per % of raise of moisture content for hardwood.

The second task of the project EFEUR 5 is about the validation of parameters for calculation of dowel-type fasteners in hardwood according to Eurocodes standards. In order to use Johansen's yield theory, engineers must work with the characteristic embedment strength in timber member. The definition of this criterion is based on a study realised by HEHLBECK and WERNER (1992) in which they suggest to take the same relation to describe this phenomenon despite the fact that they prove that the hardwood is better than softwood. As a result, a better promotion of hardwood in constructions couldn't be realised without a better description of connections.

More than 600 tests of embedding strength realized according to EN 383 standard were realized with different angles between effort and grain direction (0 and 90°) and with different diameters of dowels (12, 16 and 20 mm). The analysis of results allows us to propose new relations for the calculation of dowels-type fasteners:

$$f_{h,0,k} = 0.103\ (1 - 0.012\ d)\ \rho_k \text{ and } k_{90} = 1{,}25 - 0.035\ d$$

Finally, 18 steel to timber connections made with 3 dowels on the same line were realized and lead us to conclude that:

- The effective number of fasteners according to equation (8.34) of EN 1995-1-1 is too optimistic for describing the fragile rupture in case the failure mode is f.
- If the thickness of the wood is important and the failure mode is j, the ductility of joints appears systematically. So it should be possible to remove the effective number of fasteners in this case.
- The coefficient Kser defined by Eurocode tends to overestimate the rigidity of joints made with Hardwood (mean density of 715 kg/m3 on the 18 tests).

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Strength grading of hardwood structural timber

P. Schlotzhauer[1], S. Bollmus[2], H. Militz[3]

[1] Department Wood Biology and Wood Products – Faculty of Forest Sciences and Forest Ecology – Georg-August-University of Göttingen, Büsgenweg 4, 37077 Göttingen, Germany, pschlot1@gwdg.de

[2]Department Wood Biology and Wood Products – Faculty of Forest Sciences and Forest Ecology – Georg-August-University of Göttingen, Büsgenweg 4, 37077 Göttingen, Germany, sbollmu@gwdg.de

[3] Department Wood Biology and Wood Products – Faculty of Forest Sciences and Forest Ecology – Georg-August-University of Göttingen, Büsgenweg 4, 37077 Göttingen, Germany, hmilitz@gwdg.de

Keywords: visual and machine strength grading, MOE_{dyn}, density, knot size, pith

ABSTRACT

At present the following European hardwood species can be utilized as structural timber, after they have been strength graded visually according to national visual strength grading standards:

- Ash (German)
- Beech (German, French)
- Maple (German)
- Oak (German)
- Poplar (German, French)
- Sweet chestnut (French, Italian)

To the knowledge of the author, machine strength grading settings, which are defined in a so-called ITT-report, only exist for sweet chestnut at present.

To achieve a more prominent integration of native hardwoods into construction as load bearing elements it is necessary to evaluate their suitability on a technological and an economical basis. Therefore, at the University of Göttingen, the strength grading characteristics of six European hardwood species were investigated. Market available dried sawn wood assortments were selected as research material. Lamellas with a cross section of 100x30 mm² and lengths up to 3 meters were strength graded visually according to DIN 4074-5 (2008). Additionally, dynamic modulus of elasticity (MOE_{dyn}) and density were determined.

Figure 1 visualizes the distribution of sorting classes, when sorting the six hardwood collectives visually according to DIN 4074-5 (2008) for boards.

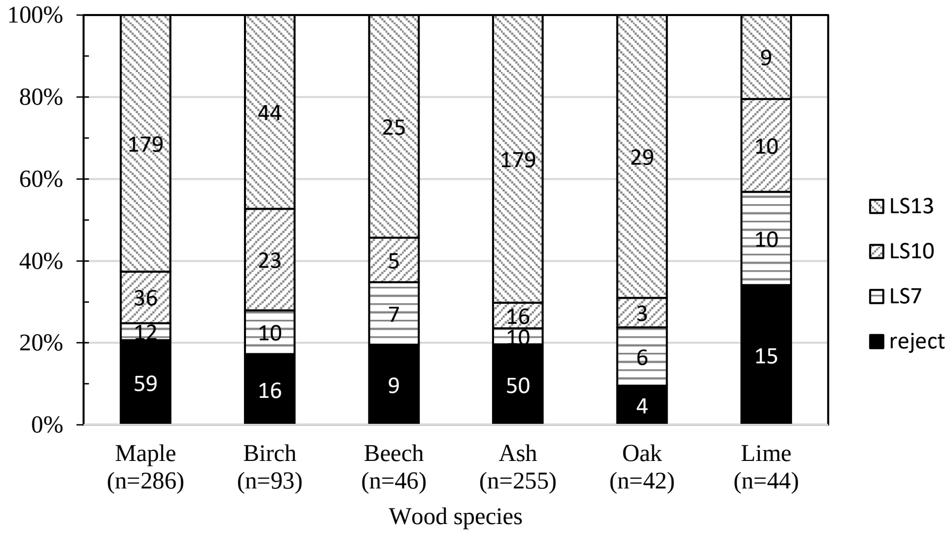

Figure 1: Visual strength grading class (according to DIN 4074-5, 2008) distribution for the six selected hardwood collectives.

Out of the investigated collectives, the collectives of the species ash, maple and European oak showed the best lamella qualities. Many big knots that led to downgrading characterized the beech and lime collectives. In lime, inbark was also abundant, which makes it less suitable for an application in construction. The influence of pith on mechanical properties is to be investigated, since in the maple, birch and ash collectives, pith was the main downgrading criterion. Ash exhibits the highest MOE_{dyn} values, but also the highest value variation. The highest densities were measured in the beech and oak collectives. At present, the market does not provide dried sawn hardwood assortments suitable as structural timber. Suitable assortments might come from round wood, which is at present consumed for energy production or from commercializing co-products from high quality products.

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Cross laminated timber development with Catalan sweet chestnut

Marcel Vilches-Casals [1], Eduard Correal-Mòdol, [2], Carmen Iglesias-Rodríguez, [3]

[1] Parc Científic i Tecnològic. Edifici H2. Planta baixa (B). 25003. Lleida. Spain. Institut Català de la Fusta (INCAFUST). marcel.vilches@incafust.cat

[2] Parc Científic i Tecnològic. Edifici H2. Planta baixa (B). 25003. Lleida. Spain. Institut Català de la Fusta (INCAFUST). eduard.correal@incafust.cat

[3] Av. Alcalde Rovira Roure, 191, 25198. Lleida. Spain. Universitat de Lleida. Escola Tècnica Superior de Tecnologia Agrària. Departament d'Enginyeria Agroforestal. carmen.iglesias@eagrof.udl.cat

Keywords: Cross laminated timber, CLT, chestnut, *Castanea sativa*, hardwood

ABSTRACT

Cross laminated timber (CLT) is a solid timber element used in construction as structural walls, ceilings or roofs and can be combined with other materials. CLT construction technology was developed in Europe in the early 1990s and since then it has become widely used for building (ESPINOZA *ET AL*. 2016). Cross laminated timber usually has an odd number of layers of softwood boards bonded together crosswise. Individual boards can be joined to one another longitudinally by finger joints and the layers are glued together. The product is offered in many qualities and strength classes. The most common coniferous used is the Norway spruce but there are also common other species like silver fir, Scots pine, larch, Swiss pine or Douglas fir. In Europe the use of hardwoods for producing CLT is low. Most research efforts have been directed to develop panels made with coniferous, the species more abundant in German-speaking countries. Other countries have large extensions of hardwood forests where the CLT production can be an alternative. In recent years, the United States began to use CLT made with hardwoods like oak, maple, ash and tulipwood because they are the most abundant hardwood species in the north American forests. These panels offer great mechanical properties and save volume of raw material because the timber is stronger and stiffer. Moreover, hardwoods have more fireproof capacity and give better appearance in comparison with coniferous CLT panels. Catalonia has a Mediterranean climate and its forests have a large variety of coniferous and hardwoods useful for structural wood products. One of the most prized hardwood is the sweet chestnut (*Castanea sativa*). In the north of the Mediterranean Catalan System there are about 27,800 ha of this tree (BURRIEL *ET AL*. 2004). The Catalan sweet chestnut has a wood with an excellent structural capacity, with a strength class D27 and a good behaviour when bonding. When producing glued laminated timber a strength class of GL36 may be expected having a good balance with the shear strength (CORREAL-MÒDOL 2013, CORREAL-MÒDOL *ET AL*. 2013). Therefore, the next step to take is to develop cross laminated timber with sweet chestnut wood according to the quality tests of the standard UNE-EN 16351:2016 (AENOR 2016), for reaching the CE marking and entering the market.

The wood used in the study was taken from monospecific chestnut forests of the Montseny and the Guilleries mountains. The wood logs were cut with a band saw to obtain boards 25 mm thick. The width was very much dependent on the diameter of the logs. The boards were dried in a log yard until the moisture content decreased to 30%. Afterwards, boards were kiln dried up to 12%. The wood was graded according to the specifications of visual quality of the standard UNE 56546:2013 (AENOR, 2013) obtaining boards with a strength class D27. The dry boards were sized to 20×85×250 mm, the prototypes CLT panels were 250×250 mm and had three or five layers. The gluing of the prototypes was done using an industrial bicomponent adhesive of

melamine-urea-formaldehyde. The gluing process was carried out in a room under controlled conditions: 20ºC and 65% of relative humidity. The wood had a moisture content of 10% and an average temperature of 24ºC. The proportion of adhesive and hardener was 100:30, the spread rate 450 g/m^2, the gluing pressure 1.4 N/mm^2 and the press time 4 hours and 15 minutes. The characterization of the product consisted on a delamination test and a shear strength test between glue layers according to the UNE-EN 16351 (AENOR, 2016). The characteristic values of the shear strength of the prototype resulted on 3.63 N/mm^2 overcoming the minimum requirements of the standards. The minimum characteristic value has to be 1.25 N/mm^2 and the minimum overall value has to be at least 1 N/mm^2. Table 1 shows the delamination results.

Table 1: Delamination and shear strength tests

Panel	Sample	$Delam_{tot}$ [%][a]	$Delam_{max}$ [%][a]
CLT 3 LAYERS	1	3.45	5.12
	2	0.00	0.00
	3	5.48	8.67
	4	0.00	0.00
CLT 5 LAYERS	5	2.06	8.23
	6	1.73	3.81
	7	1.48	4.64
	8	0.00	0.00

[a]The bonding is sufficient, if the $Delam_{max}$ does not exceed 40% and the $Delam_{tot}$ does not exceed 10%

The results show that the chestnut wood has a gluing potential comparable to other species frequently used by industry. Nevertheless, further research is needed to have a comprehensive about the potential of this panels and see if it is feasible to develop projects to an industrial scale.

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Innovative processing technologies of inferior beech assortments for the production of lamellas for glulam production "InnoBuLa"

Alexander Englberger[1], Matthias Zscheile[2]

[1] Hochschulstraße 1, 83024 Rosenheim, Germany, University of applied sciences Rosenheim, alexander.englberger@fh-rosenheim.de

[2] Hochschulstraße 1, 83024 Rosenheim, Germany, University of applied sciences Rosenheim, matthias.zscheile@fh-rosenheim.de

Keywords: Beech glulam, inferior beech lamellas, sorting catalogue, modulus of elasticity, dynamic modulus of elasticity

ABSTRACT

The research work carried out so far focuses on high-quality beech assortments, i.e. the so-called carpenter's ware, for the production of glulam. Compared to the cheaper softwood product, the beech glulam produced is not competitive in this market, even though the higher strength of beech wood compared to softwood has been proven. These results, however, show the possibility to produce glulam with the same static properties in narrower dimensions.

This project aims to prove beech glulam produced with a certain proportion of inferior trunk sections of beech lamellas can meet or exceed the standard strength characteristics for the lamellas as well as for a glued beam.

Log characteristics such as length, diameter, knots, crookedness, defoliation, and red heartwood content are important for the scope of the project. A random sample size of 80 beech logs of grades 2b and 3a were selected and characteristics recorded. After examination, creel cut of the trunks to produce boards for quality grading using the classes of A, B, and less than B.

"InnoBuLa" uses beech lamellas of grade C or worse which are the low-valued by-products of sawn timber production typically used for energy production or packaging production to create a high value product. The static and manufacturing properties of lower quality beech lamellas are investigated including the properties of tensile strength, dynamic modulus of elasticity, tensile modulus of elasticity, bulk density and knots. Common to the process of producing glulam, finger-joints will be used to connect each lamella. The tensile and bending strength of the finger-joint is determined in accordance with DIN EN 14080 and DIN EN 408.

Based on the results of this testing, a sorting catalogue is drawn up in order to meet or exceed the static strengths of commercially available spruce laminated timber. Afterwards, the maximum permissible growth characteristics of beech wood assortments of poorer qualities is determined, taking into account the prescribed strength properties of construction timber (DIN EN 338 and EN 1194).

The results of this research project can be used to update existing standards, because the investigations of this research contract resulted to an improved material use of beech assortments of inferior qualities.

Parallel Session IX.
New hardwood product approaches

Technology Road Map for Hardwood in Lower Austria

Christian Hansmann[1], Christian Huber[1], Alfred Teischinger[2]

[1] Wood K plus – Competence Centre for Wood Composites and Wood Chemistry, Area Wood Materials Technologies, Austria, c.hansmann@kplus-wood.at

[2] BOKU University, Vienna, Institute of Wood Technology and Renewable Materials, Austria, alfred.teischinger@boku.ac.at

Keywords: Technology road map, hardwood, innovation, Lower Austria

ABSTRACT

Hardwood is a major renewable und sustainable resource in Lower Austria with a great potential. National forest inventory data show an increasing amount of hardwoods, which is true for both, pure and mixed stands. However, usage stagnates and partially significantly decreases, leading to decreasing raw material prices for mass assortments like beech. But from an economic and ecological point of view, an increased integration of hardwoods in a cascading wood utilisation is necessary.

Silvicultural remodelling processes, intensified by the climate change, call for a shift away from focusing on softwoods. The retention of established technologies is only possible to a very limited extent when substituting softwood by hardwood. As a consequence, a rethinking of classical wood technology processes is necessary for consistent and satisfying product quality. The here presented technological road map for hardwood in Lower Austria shall help that his rethinking process does not take place besides economic framework conditions and market needs. The roadmap shall rather serve as an initial impulse for a technological planning process, which is carried out in collaboration with experts from industry and science.

This way, a technology road map functions as a foresight model assuming that the future should be created proactively. As several examples from the past have shown, a technology road map is a proven method to address future industrial challenges, also in the wood sector (ANONYMOUS 2003, 2005, 2006, TEISCHINGER AND TIEFENTHALER 2008). A technology roadmap is usually grouped in three key process stages:

- Where are we today? (current situation, market, technology, players, competitors, etc.)
- Where do we want to go? (setting of specific targets as well as a visionary outlook)
- How can we achieve this? (research, innovation, education and training, etc.)

Lower Austria is the most important regional hardwood supplier in Austria (Fig. 1), but only a small amount is processed in Lower Austria and the bigger part flows to other federal countries in Austria. As generally known, beech is the predominant species. For an overview about the industrial hardwood processing, a schematic material flow chart was created where operations and chains regarding harvesting, processing and machining as well as material distribution within the hardwood sector are displayed. As one important fact, the high amount of hardwood usage for energy production (app. 70 %) should be pointed out.

Based on a literature research, different categories of "top priority research and application fields" were identified and systematically evaluated, the latter also including a workshop with internationally renowned hardwood experts. As an example, the following hardwood application fields were considered: sawn timber, veneers, plywood, fibreboards, pulp and biorefinery. Different levels of research risk, technological readiness level and framework conditions led to different levels of potential.

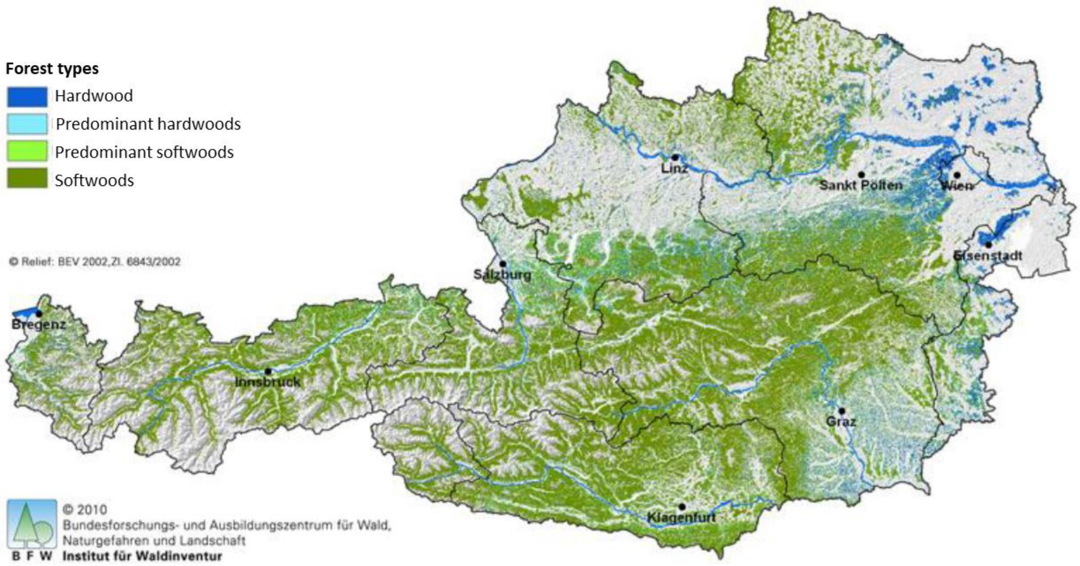

Figure 1: Forest types in Austria (according to BFW 2010)

Based on this evaluation, workshops and interviews with stakeholders led to an assumption which technology paths could be promising. As one output, it was shown that two parallel strategies can be successful: specific development steps could be advantageous for distinct, established process categories leading to incremental developments on the one hand. On the other hand, a more open innovation process is needed for a rethinking of classical wood technology processes, which includes the willingness for strategic, long term research work beyond the state of art. Possible funding was pointed out on a national and international level, whereby the importance of international cooperation beyond the boundaries of Lower Austria will gain importance in the future.

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Extended Utilization of Forest Production & Wood Material: Hardwood Usage from Native Properties to Wood Modification

Peter Rademacher[1(2)], Radim Rousek[1], Petr Pařil[1], Jan Baar[1], Stanislav Horníček[1], Zuzana Paschová[1], Róbert Németh[2] ,Tamás Hofmann[2], Fanni Fodor[2], Gerald Koch[3], Andreja Kutnar[4]

[1] Mendel University in Brno, Zemědělská 1, CZ-613 00 Brno/ CZ, peter.rademacher@mendelu.cz

[2] University of Sopron, Bajcsy-Zs. u. 4, H-9400 Sopron/ HU, nemeth.robert@uni-sopron.hu

[3] Thünen Institute of Wood Research, Leuschnerstr. 91, D-21031 Hamburg/ DE, Gerald.Koch@ti.bund.de

[4] University of Primorska, Muzejski trg 2, Glagoljaška 8, SI-6000-Koper/ SI, Andreja.Kutnar@upr.si

Keywords: Extended biomass production, lesser used wood species, wood modification, high use value for recovered wood, wood based panels, renewable sources for adhesives

ABSTRACT

Climate change, request for sustainability and restrictions in availability of fossil energy and material sources are more and more limiting their use. But also regenerative sources, like wood, straw or other renewable biomass pools are limited in quantity and quality. Due to this demand, both producing industry and consuming customers have to make sure they act in a highly saving and qualitative way. Additionally, the spectra of potential biomass sources have to be widened and adapted to their future use as far as possible. Tools to realize this are:

- Extension of the area and method of biomass production (forest, agriculture, plantations, harvest residues) → Examples: short rotation coppice & crown usage
- Widening of the spectra of potential suitable tree and wood species → Example: seldom or lesser used wood species
- Improvement of the wood properties, adapting of the wood quality to future usage → Example: wood modification
- Higher use of recovered wood, development of an integrated collection and utilization system in the EU, request for highest possible use value → Example: Material/ solid wood use of recovered beams, doors or window frames
- Utilization of more steps in the added value chain of wood, including material > chemical > energy usage steps → Examples: 2nd step of solid wood usage & wood based panels (WBP) & wood polymer compounds (WPC) & liquefaction of wood
- Increase in the sustainability and renewability level in wood production, processing and utilization → Example: renewable sources for processing, drying, adhesives, surface coating and impregnation agents (RADEMACHER ET AL. 2016).

A European research consortium is working on these demands. Processes can be (Fig. 1):

a) 1a) 3-10x higher biomass production in short rotation coppices with poplar, willow or Robinia
b) 1b) 2x additional biomass supply compared to stem use only by crown utilization in forests
c) 1c) Widening of higher value applications of wood, like furniture from Mountain Ash (Leder)

d) 1d–f) Improved dimensional and durability properties of SRC-poplar (native: d) after Robinia extract impregnation without (e) and with additional water leaching (f; photos: Rousek)
e) 1g) Possibilities of chipped recovered wood residues, for example for particle boards (Mohr).

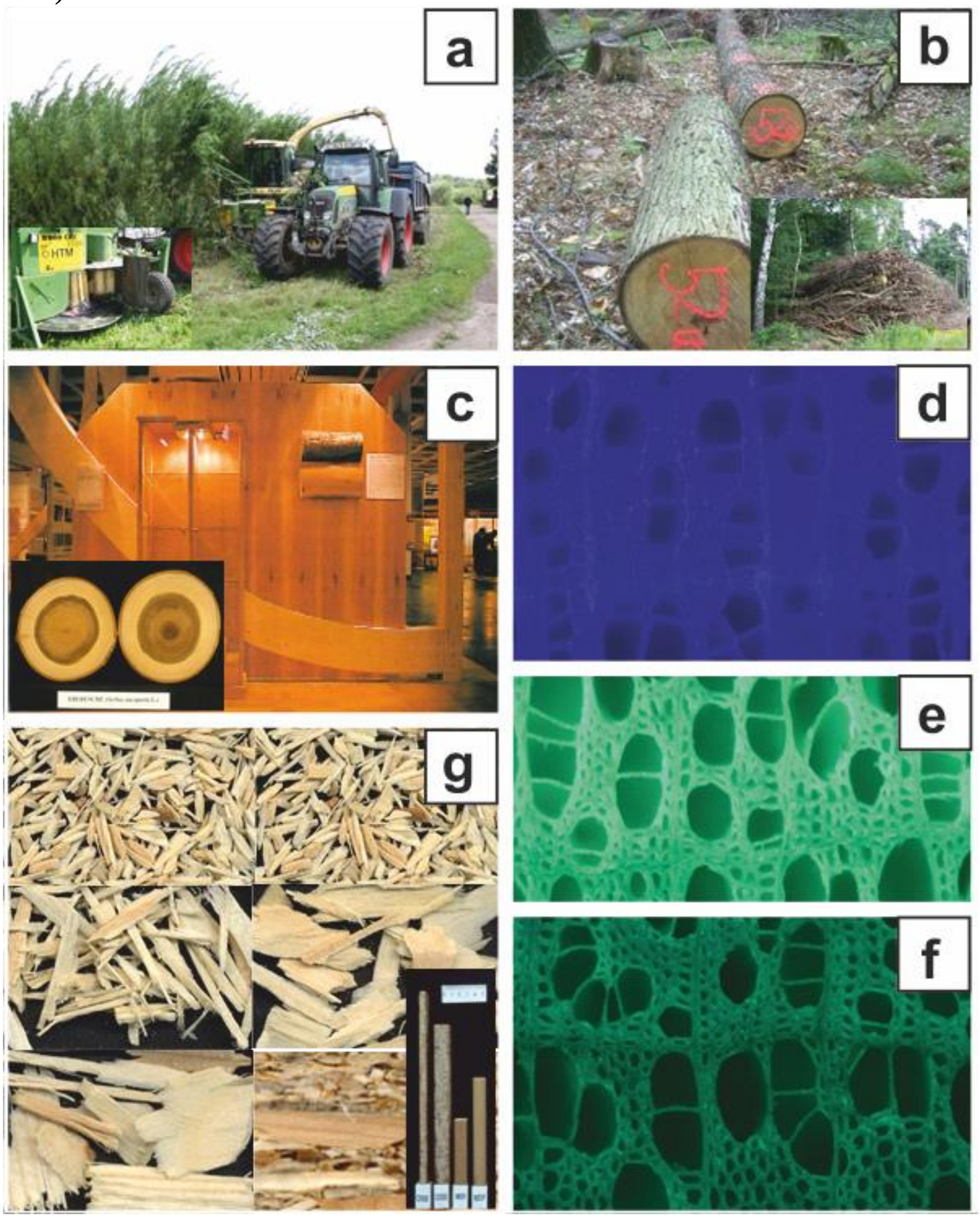

Figure 1a-g: Examples of widening of wood production and application (sources and explanations in text)

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European Hardwoods Innovation Alliance: first results of a European survey on hardwoods research needs and priorities

Barbara Rovere[1], Ana Slavec[2], Uwe Kies[3]

[1] Livade 6, 6310 Izola, Slovenia, InnoRenew CoE, barbara.rovere@innorenew.eu

[2] Livade 6, 6310 Izola, Slovenia, InnoRenew CoE, ana.slavec@innorenew.eu

[3] Rue du Luxembourg 66, 1000 Brussels, Belgium, InnovaWood, uwe.kies@innovawood.com

Keywords: innovation, scientific collaboration, social network analysis, survey.

ABSTRACT

Links between knowledge producers (researchers) and policy makers are a precondition to optimal utilization of knowledge to achieve impact (CAPLAN, 1979). The European Hardwoods Innovation Alliance (EHIA) is a trans-national collaboration of experts from wood science and related fields that aims to improve forest-based value chains - predominantly based on softwood species - by supporting efforts that promote the valorisation of underused hardwood species.
As a kick-off activity in 2016, an open questionnaire was carried out to which stakeholders in research and industry contributed their ideas on future research and innovation needs for wider use of hardwoods in Europe. In total, 199 different contributors from 38 countries participated and provided 219 validated innovation ideas. Respondents also provided a list of keywords and classified their contributions in one of the 15 different themes (Fig 1). They were also asked to assess the size of the budget, the risk involved and market relevance.

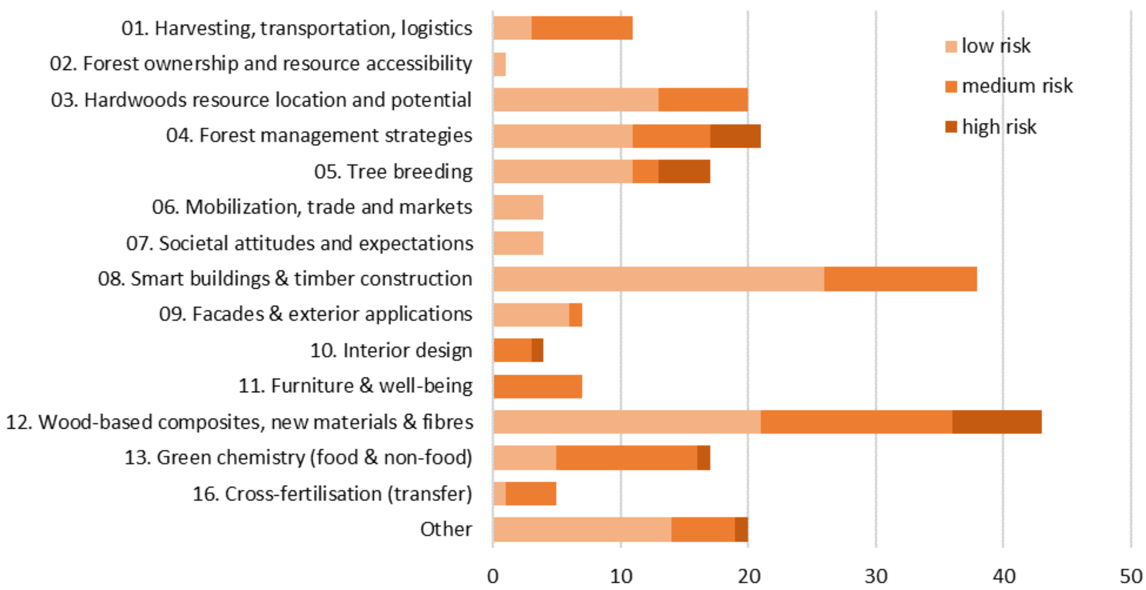

Figure 1: Ideas related to 15 different themes

Cohesive collaboration networks of scientists within and across knowledge domains are of key importance for high-quality scientific production and to sustain its creation and diffusion (LAMBIOTTE ET AL. 2009). The structure of scientific collaboration networks can be analysed with network analysis (NEWMAN 2001, BARABASI ET AL. 2002). We decided to use social network analysis (SNA) to identify potential collaborations and formation of new research consortia between participants in the EHIA survey. A two-mode network was created with researchers as the first set of units and topics as the second set of units, which was then transformed to a one-mode network (Fig 2). We found that most ideas belong only to one topic, while a small number of researchers suggested research programmes on more than one topic and thus represent intergroup nodes in the network. These point to important thematic priorities in the hardwoods research community.

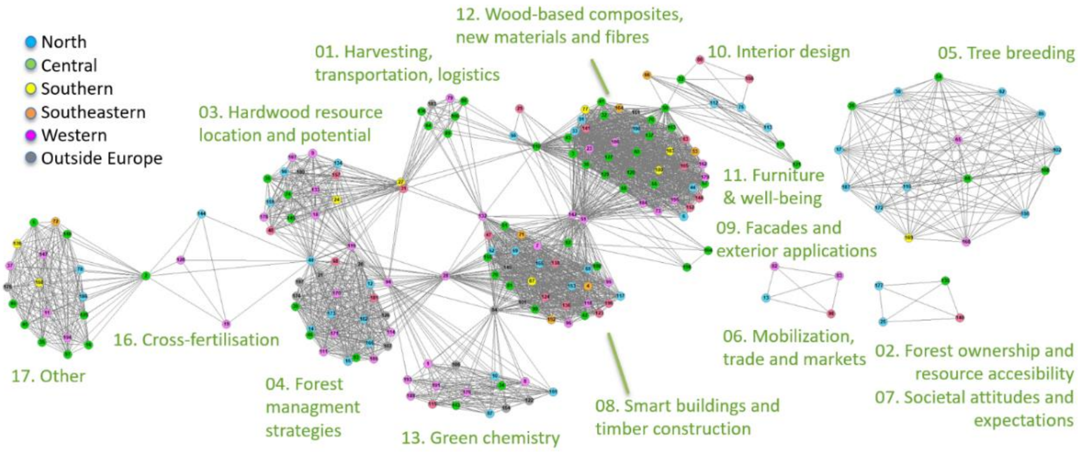

Figure 2: Network analysis of respondents

However, the existing data does not an address fostering better transfer and exchange between researchers and policy makers. An additional survey is needed that would include a wider array of actors, especially industry and public authorities, to study the needs for diffusion of knowledge in a wider perspective. Based on the insights gathered from the 2016 survey, a broader follow-up survey is being developed by the InnoRenew CoE and InnovaWood, which will allow collection of advanced data to further our understanding of the knowledge creation and diffusion processes in the field of hardwoods research and to improve its exploitation in the forest-based sector.

ACKNOWLEDGEMENT

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Parallel Session X.
Product design and marketing initiatives

Thermal modification of lesser-known wood species with the hygrothermolytic FirmoLin® process

Edo Kegel[1], Wim Willems[2]

[1] Veerpoortwal 20, 6981BS Doesburg, The Netherlands, Edo Kegel Concultancy & Advice, edo@edokegel.nl

[2] Grote Bottel 7b, 5753PE Deurne, The Netherlands, FirmoLin Technologies BV, w.willems@firmolin.eu

Keywords: innovation, hardwood, wood properties, substitute market, use-class 3,

ABSTRACT

BURMESTER (1973) described a process for wood dimensional stabilization by heat treatment of kiln-dried wood (around 10%MC) in a closed vessel. During this process, the pressure inside the vessel will automatically increase by the emission of thermal conversion products from the timber and the vaporization of wood moisture. The obtained pressurized gas inside the process vessel is typically mainly composed of partially saturated steam, establishing an equilibrium with the wood moisture content (MC). This results in nearly stress-free thermally modified timber and correspondingly low loss of timber quality by checks and deformation, compared to heating in vacuum or under (near-)atmospheric pressure, where the timber is essentially oven-dried. On the other hand, hydrothermal conditions, may lead to significant structural strength loss, since cross-linking (curing) reactions are strongly inhibited in the fibre-saturated wood cell wall (ALTGEN ET AL. 2018, BOONSTRA ET AL. 1998). In principle, the initial MC can be optimized to run the Burmester process within a window of hygroscopic conditions, avoiding the detrimental effects by either dry or hydrothermal heating. However, the controllability of the Burmester process is poor, being not solely dependent on the initial MC, but also on the reactor filling degree, the density of the timber, the heating rate as well as the thermal wood modification rate.

The hygrothermal heating process has been further developed into the FirmoLin® process (WILLEMS 2009) through active partial steam pressure control, to obtain fully defined hygroscopic conditions in every stage of the entire heat treatment cycle. The FirmoLin process takes an intermediate position between the extremes of dry heating in vacuum or near-atmospheric pressure on one hand and hydrothermal treatments in saturated steam or hot water on the other hand. The hygroscopic conditions are determined by the treatment temperature T and the steam pressure P, defining the relative humidity $RH = P / P_{sat}(T)$, where P_{sat} is the saturated steam pressure at temperature T. Having two independent variables (RH, T), the MC can be controlled independently from the wood modification reactions. With increasing MC at reaction conditions, the character of wood chemical reactions shifts from dehydration and crosslinking reactions towards depolymerization, with mechanism provides a means to adjust mechanical properties of the final products.

Thermal wood modification has been developed in the 1990s into a market-leading large-scale treatment technology for the sawmill industries (ALA-VIIKARI AND MAYES 2009). In the last decade, this technology has spread around the world, almost exclusively producing commodity products in cladding and decking application. These high-volume applications do not employ the full potential of thermal wood modification as a flexible technology to engineer the materials properties to specification. The potential for thermal wood modification to upgrade lesser-known wood species for market opportunities has neither been utilized yet. One of the reasons for the limited differentiation in thermally modified products and wood species is the

tedious and costly process of optimization of the dry heating process, needed to solve low-yield problems. Being a medium-scale thermal wood modification technology with an inherently high production yield by keeping wood in an equilibrium moist state, the hygrothermal heating process may be optimally used for product development of lesser-known wood species. This technology therefore can enhance the forest utilization and stimulate the local wood working industry for new value-added (semi-finished) wood products.
In this contribution, some project examples are shown implemented with lesser-known wood species from Africa (Fraké (*Terminalia superba*), Movingui (*Distemonanthus benthamianus*)) and South-America (Acacu (*Hura crepitans*), Amapa (*Brosimum utile*)), successfully modified by hygrothermal wood modification.

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Eucalyptus globulus single family house in Spain after 16 years of exposure

David Lorenzo[1], Juan Fernández-Golfín[2], Manuel Touza[3], Alfonso Lozano[3]

[1] Address of first author, including country, affiliation, and email address

[1] Engineering for Rural and Civil Development, University of Santiago de Compostela, 27002 Campus s/n Lugo, Spain, davidlorenzofouz@gmail.com

[2] Forest Research Centre (CIFOR) National Institute for agricultural and Food Research and Technology (INIA), 28080 Madrid, Spain, golfin@inia.es

[3] GAIN CIS-Madeira, Galicia Technological Park, 32901 San Cibrao das Viñas, Ourense, Spain, manuel.cesareo.touza.vazquez@xunta.es

[4] Construction Engineering Area, EPS, Edificio Oeste nº 7, Campus de Gijón E-33203 Gijón, Spain, alozano@uniovi.es

Keywords: Eucalyptus, performance, design, house.

ABSTRACT

From last century, in the country side in Spain is common to find wooden houses. The reason is mainly due the improvements in glues, materials, design by computer and processing in factories. All these technological advances have facilitated the development industrialized systems cheaper. However, the variety of row materials, designs and construction systems, combined with some hard climates, could have as result in some cases pathological problems associated to wood destroying fungi, insects an aesthetics.
The wood species selected and the design details are fundamentals for performance and durability of the timber houses. The wood degradation depends on firstly on the wood specie selected but also depends on driven rain and winds, design details, joints and maintenance.
This paper presents the performance of an *Eucalyptus globulus* single family house built in 2002 in north Spain, using entirely sawn and glued laminated *Eucalytus globulus* heartwood in all elements of the house: Structure, flooring, stairs, windows, galleries, roofing, carpentries, etc., without using preservatives and it was designed considering very well detail designs as well as maintenance during its service life.
After more than 16 years, the performance of all wood elements of this single family house is very good, without pathological problems and continues to serve their original purpose.
This house constituting a prime example of the versatility of this wood in structural and decorative wood elements. It is worth pointing out that all joins between structural components have been assembled with traditional techniques and without using metallic elements.

***Figure 1: Eucalytus globulus* house in Spain.**

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How to enrich forest information by the analysis of the hardwood selling prices from public forests?

Case study, hardwood in Bourgogne Franche-Comté, France

Jean-Michel Leban[1, 2], Lucile Savagner[3], Jean-Baptiste Schwebel[4], Holger Wernsdorfer[5], Jean-Daniel Bontemps[2]

[1] INRA/BEF 54280 Champenoux, France, jean-michel.leban@inra.fr

[2] IGN//Laboratoire de l'Inventaire Forestier, 54000 Nancy, France

[3] INRA 54280 Champenoux, France, lucile.savagner@inra.fr

[4] Office National des Forêts , 21000 Dijon, France, jean-baptiste.swebel@onf.fr

[5] AgroParisTech, 54000 Nancy, France, holger.wernsdorfer@agroparistech.fr

Keywords: prices, quality, forest inventory, hardwood, Quercus

ABSTRACT

The resolution of the national forest inventory data is not sufficient to provide for industry, at the local level, accurate information on the volumes and quality of the forest resources. The question that arises is how to enrich the forest information?

In France every year, the National Forest Service organizes sales of timber from public forests. It records the prices paid, broken down by species and diameter classes, lot specific composition, forests locations and identity of the end-user buyers.

We hypothesis that the use of these public sales data combined with the information available in the original forest management plans could improve the knowledge of the forest resources at the local level.

The analysis was performed on the public sales data recorded between 2008 and 2015 in the Burgundy region. Altogether, these data represent more than, 4000 lots, one million m3, 600.000 individual tree stems. Each harvested lot is at least described by the forest location, the number of stems, the total volume, the proportion of oak and the price paid.

The results show that the oak compositional index of lots has a major influence on the price paid by the end-users. For "pure oak lots", there is a robust relationship between the price / m3 and the DBH. For "mixed harwood lots" more than 70% of the variance of the price / m3 is explained by DBH and the composition index of the lots.

To date, we were unable to establish any direct relationship between the information available in the management documents of the forests from which the lots were harvested and the prices paid for the lots.

The prospects that emerge from this study are

(i) the use of linear regressions obtained between the past selling prices, DBH and the lot specific composition index can be used for the estimation of the future income, including the possibility of maximizing the income according to the composition of the lots,

(ii) for lots with a high proportion of oak, it seems possible to convert the range of variation of the prices per DBH into pseudo quality classes, thus allowing to enrich the scarce wood quality information available in the forest inventory data bases

Finally, it appears possible to enrich the forest information as soon as it will possible to compile the results of the annual public sales with a new layer onto the forest inventory maps, including the geolocalized selling prices of public sales and the end users typology.

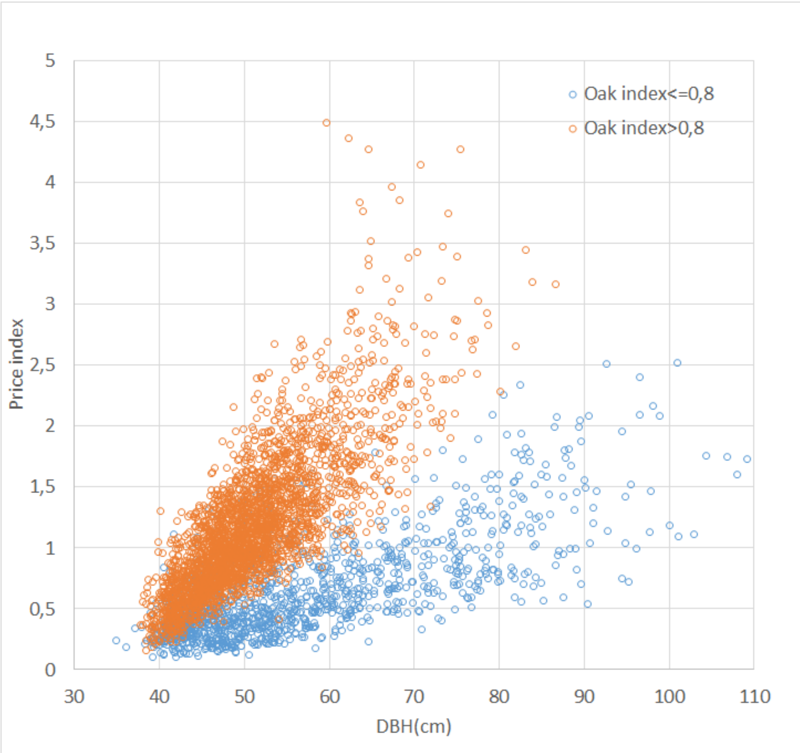

Figure 1: each dot represents a sold lot. Price index is proportional to DBH. The slope of this linear relationship is higher when Oak proportion is higher than 0.8 (orange colour) and lower for proportion of oak is lower than 0.8(blue colour). The other hardwood species are mainly beech, ash and hornbeam

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Hardwood Research and Utilisation in Europe

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