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Sopron (Hungary)
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Hardwood Research and Utilisation in Europe

Eco-efficient Resource Wood with special focus on hardwoods

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Eco-efficient Resource Wood with special focus on hardwoods

Sopron & Vienna, 2014. (14) 15-18th September

RÓBERT NÉMETH & ALFRED TEISCHINGER & UWE SCHMITT
editors

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PREFACE

Wood science and technology may deal with general issues of wood and its utilization. Due to the huge variability within the great number of wood species, many of the specific research issues are focused on a specific wood species.

Wood material properties, the various conversion processes from the raw material wood to intermediate and final products, modification processes and the performance of the final product are mostly related to a specific wood species.

In many European regions softwoods are the predominant wood species which are well suited for the various applications in the building sector. Due to specific soils and climatic conditions, the increasing importance of semi-natural forest management, climatic change etc., the share of broad-leafed trees (generally referred to as hardwoods) within the forest stock is increasing rapidly, reaching a percentage of 25 – 50% of the total forest area.

We realize that the increasing stock and the potential harvest of hardwoods does not match the demand on the market. A significant share of harvested hardwoods is not allocated to proper utilization paths but is used as fuel wood. New and improved tracks for a competitive hardwood utilization need to be found based on hardwood research results.

We are very happy that the current annual convention of the International Academy of Wood Science is linked to the bi-annual conference series „Hardwood Research and Utilization in Europe“ with selected presentations and posters.

We hope to introduce new knowledge into the sector contributing to a research- driven innovation in the hardwood sector.

We would like to thank the International Academy of Wood Science and all the academic partners for their collaboration in organizing the conference and hope to provide a good documentation with the current proceedings.

Alfred Teischinger

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KEYNOTE SPEECH

Wood Resources in Europe in the Future

F. Hapla

Georg-August University of Göttingen, Germany

fhapla@gwdg.de

ABSTRACT

Almost a third of Germany’s land area, i.e. 11.1 million hectares, is covered with forests. The wood stock is larger than that of the traditional forest countries, Sweden and Finland. The main use of Germany’s forests concerns just a few tree species. At present, several softwood and broad-leaved tree species play a minor role in forestry. Spruce accounts for the largest share among the tree species (28 %), followed by pine (24 %), beech (15 %) and oak trees (10 %). Since 2010 the energetic use of raw wood and wood-based products is higher than the material use in Germany. Wood’s share - including industrial wood residues and waste wood – in respect of energy generation as well as private households’ wood consumption for energy purposes alone increases steadily. The heterogeneous situation of the raw wood supply and demand in the European Union is presented against the background of raw wood shortage in the future.

At present, several factors promote a development which can lead to a medium-term supply shortfall on the German timber market regarding the coniferous raw wood. The main reasons are a strong prospective advancement of deciduous tree species and an implementation of forest policy abandoning programs. Several possible approaches for securing raw wood supply are discussed: Tree species with a promising future should be strongly promoted from a sustainable forest management as well as from innovative wood utilisation point of view. Mobilisation of unused timber stock in small private forest area and short rotation plantations on farmland are additional possible approaches. Further renewable resources are available in the landscape area**.**

Renewable resources from agriculture and forestry can basically be used as raw materials, as energy or both. The quantities and qualities of the raw materials, the market situation and the political conditions impact the subsequent production processes strongly. All three aspects need to be considered when defining resource efficiency. Raw materials’ quality and quantity can be influenced by processing and, in the long term, by research and development, but they are also always liable to natural processes like annually changing weather conditions, or unpredictable catastrophes, also caused by climate change.

Combined production as well as the reuse and recycling of by-products on an industrial scale is well established in respect of forestry resources. Likewise, product and resource substitution and their effects concerning the supply and demand sides play an important role. However, the increasing substitution of fossil-based energy production with bio-energy concepts leads to a competition for renewable products on the market. Utilisation conflicts thus occur between energy use, material use and food production. Open research questions concern the cascading use of bio-materials, since at present often only certain parts of a plant can be used in one or another application.

POSTER FLASH PRESENTATIONS I

Investigation of carbon sequestration on different fast growing tree species

A. Benke[1], Sz. Komán[2], S. Fehér[3], A. Borovics[4], K. Rédei[5], E. Führer[6]

[1] NARIC Forest Research Institute, Hungary; benkea@erti.hu

[2] University of West Hungary, Institute of Wood Sciences, Hungary; szabolcs.koman@skk.nyme.hu

[3] University of West Hungary, Institute of Wood Sciences, Hungary; sandor.feher@skk.nyme.hu

[4] NARIC Forest Research Institute, Hungary; borovicsa@erti.hu

[5] NARIC Forest Research Institute, Hungary; redeik@erti.hu

[6] NARIC Forest Research Institute, Hungary; fuhrere@erti.hu

Keywords: carbon sequestration, short rotation coppice, biomass production

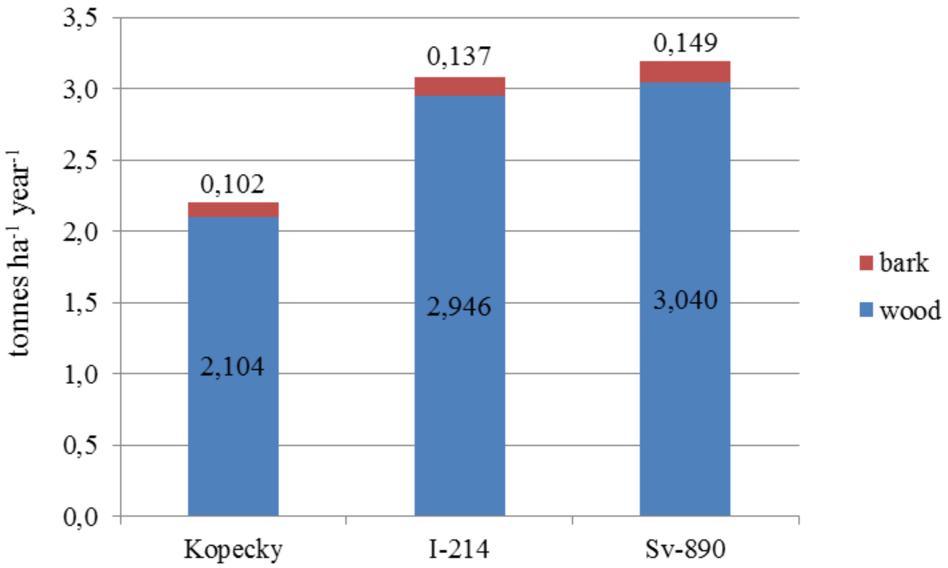
ABSTRACT

In this study we investigated the aboveground biomass production and the carbon content of woody biomass on a short-rotation coppice established with different poplar clones. The SRC was established in a nursery garden of NARIC Forest Research Institute (Sárvár-Bajti) in March 2007. The density of the plantation is 8400 trees per hectare (3,0 x 0,4 m). The annual yields were calculated from three-year biomass yields, measured at the end of the second harvesting cycle. The annual yields of three hybrid poplar [*Populus* × *euramericana* (DODE) GUINIER] clones planted in short-rotation coppice of Bajti ranged between 4,64 and 6,63 oven dry tonnes per hectare (Table 1), which can be considered average according to biomass data of different experimental foreign SRC plantations [5,3 odt ha^{-1} year^{-1} (DILLEN ET AL 2013), 1,52-7,22 odt ha^{-1} year^{-1} (VERLINDEN ET AL. 2013)].

Table 1: Fresh and oven dry aboveground biomass production of three hybrid poplar clones in Bajti at the end of second harvesting cycle

Genotype	Average yield [t ha^{-1} 3 years^{-1}]	Standard deviation [t]	Annual mean [t ha^{-1} year^{-1}]	Dry matter content [%]	Annual mean [odt ha^{-1} year^{-1}]
Sv-890	45,50	13,10	15,17	41,70	6,63
I-214	45,18	14,52	15,06	40,67	6,40
Kopecky	29,04	6,89	9,68	45,68	4,64

Wood and bark samples were collected in the experimental plantations from three height level of the trees (lower, medium and the upper third) in order to determine the carbon content of the plants (samples from the upper third were not separate for bark and wood). Based on our measures the carbon content of hybrid poplars (clones showed in Table 1) wood samples from the lower third of the plants is nearly the same (ranged between 49,2-49,9 %).
Carbon content of aboveground biomass per hectare was determined using mean annual yield data and absolute dry matter content of woody biomass measured in laboratory. The calculations were carried out separately for wood and bark as well. The bark content was set to 4,83% according to THARAKAN ET. AL.(2003).
The poplar clones Kopecky, I-214 and Sv-890 stored 2,206, 3,083 and 3,189 tonnes carbon in their aboveground woody biomass per hectare per year, respectively (Figure 1).



1. Figure: Annual carbon sequestration in aboveground woody biomass of three poplar clones in Bajti

The very first results of the investigation show no significant difference between the carbon content of aboveground woody biomass of the investigated hybrid poplar clones. Since they store nearly the same amount of carbon per unit of wood weight, differences in total carbon storage basically determined by differences in growth and biomass production of the plant material.

REFERENCES

DILLEN, S.Y., DJOMO, S.N., AL AFAS, N., VANBEVEREN, S. AND CEULEMANS, R. (2013) Biomass yield and energy balance of a short-rotation poplar coppice with multiple clones on degraded land during 16 years *Biomass and Bioenergy*, **56**, 157-165.

THARAKAN, P.J., VOLK, T.A., ABRAHAMSON, L.P. AND WHITE, E.H. (2003) Energy feedstock characteristics of willow and hybrid poplar clones at harvest age *Biomass and Bioenergy*, **25**, 571-580.

VERLINDEN, M.S., BROECKX, L.S., VAN DEN BULCKE, J., VAN ACKER, J. AND CEULEMANS, R. (2013) Comparative study of biomass determinants of 12 poplar (*Populus*) genotypes in a high-density short-rotation culture *Forest Ecology and Management*, **307**, 101-111.

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Transformation of wood structure at shape memory effect

G.A. Gorbacheva[1], B. N. Ugolev[1], Yu. A. Olkhov[2], V.G. Sanaev[1], S.Yu. Belkovskiy[1]

[1] Moscow State Forest University, Department of Wood Science, 1st Institutskaya street, 1,Mytischi, Moscow Region, 141005 , Russia, gorbacheva-g@yandex.ru, ugolev@mgul.ac.ru, rector@mgul.ac.ru, belkovskiy@ro.ru

[2] Institute of Problems of Chemical Physics of the Russian Academy of Sciences, Department of Polymers and Composite Materials, Academician Semenov avenue 1, Chernogolovka, Moscow Region, 142432, Russia, olkhov@icp.ac.ru

Keywords: smart materials, memory effect of wood, frozen strains, thermomechanical spectrometry, transformation of molecular-topological structure

ABSTRACT

Creating the new smart materials is one of the perspective tendencies in material science. Wood is a complex of biopolymers, it belongs to smart materials. As an eco-friendly, eco-efficient, technically advanced material, wood and wood based materials are gaining importance among modern materials. Possibility of giving of a complex of new properties, effective application of coatings, recycling, waste disposal are competitive advantages of wood comparing with artificial materials. The shape memory effect (SME) is the dominant feature of wood as a natural smart material. The SME is latent property of wood. It was experimentally discovered at the end of the 1970s, research of deformative conversions at various histories of deformation, visualization and quantification of SME, the multi-shape memory effect of wood were conducted by us (UGOLEV 1976, UGOLEV 1986, UGOLEV 2011, UGOLEV et al. 2011, UGOLEV et al. 2013, UGOLEV 2014). The shape memory effect of wood is based on quazi-residual frozen strains, they are the carrier of memory effect of wood. They were detected by us in wood fastened specimen at drying in the early 1960s (UGOLEV 1961). Frozen strains take place under the controlling load influence while wood stiffness increases at drying or cooling and are caused by temporary reconstruction in wood nanostructure.

Method of thermomechanical spectrometry (OL'HOV et al. 1992, OLKHOV and JURKOWSKI 2005) was used to research the changes in wood structure during the formation of frozen strain. The components of strains, shape-memory quantities (Rr and Rf), relaxation parameters, the phase state and molecular characteristics of the fragments of the macromolecules in the structure of topological blocks of wood were determined for beech sliced veneer samples (200x15x0,6 mm, LxTxR). Transformation of topological structure of wood at shape memory effect is shown on the Fig. 1. The sample with the permanent shape has topologically diblock amorphous-cluster structure of the pseudonetwork structure with a ratio of blocks 0.76:0.24. During programming the frozen strains are formed, sample remembered temporary shape. The substantial transformation of topological structure of wood is observed, it becomes triblock, the high-temperature amorphous block of pseudo-network structure is formed. The ratio of low - and high-temperature amorphous and cluster blocks is 0.26:0.3:0.44. After returning to the initial conditions the frozen strains disappeared and the permanent shape is recovered. The initial diblock structure of wood with some quantitative changes of molecular relaxation characteristics is restored because of complete structural degradation of the high-temperature block. The ratio of blocks is 0.83:0.17, the portion of the amorphous block increases due to irreversible plastic strains.

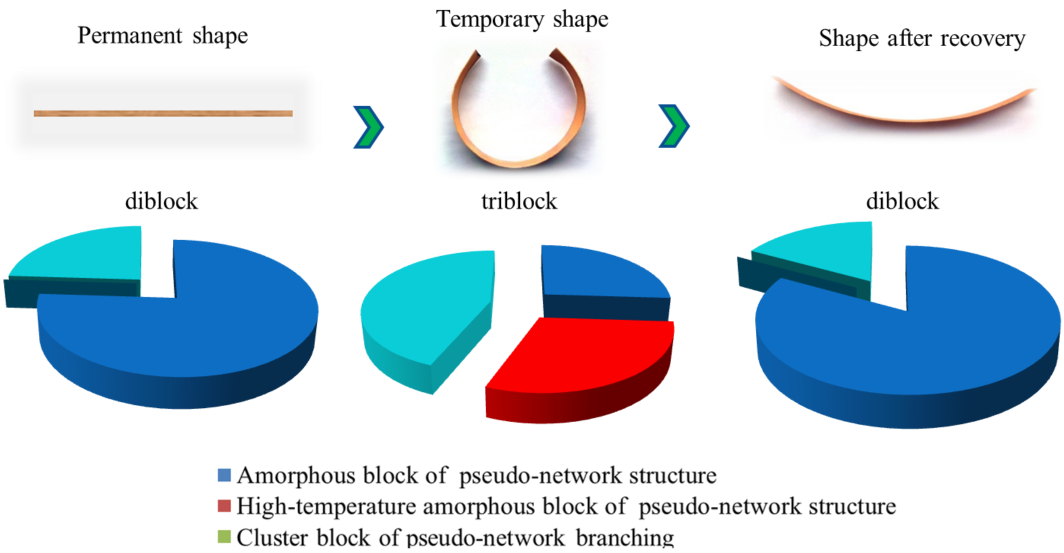

Figure 1: Transformation of topological structure of wood at shape memory effect

REFERENCES

OL'HOV, Yu.A., IRZHAK, V.I., BATURIN, S.M. (1992) The way of definition of molecular-mass distribution of polymers. Patent №1763952 of Russian Federation.

OLKHOV, Yu.A., JURKOWSKI, B. (2005) On the more informative version of thermomechanical analysis at compression mode - A review. *Journal of Thermal Analysis and Calorimetry*, **81**(2), 489-500.

UGOLEV, B., GORBACHEVA, G., BELKOVSKIY, S. (2013) Quantification of wood memory effect. In: *Proceedings of the IAWS meeting «Wood the Best Material for Mankind» and the 5th International Symposium on the «Interaction of Wood with Various Forms of Energy»,* September, 2012 , pp. 31-37, Zvolen: Publishing House of Technical University in Zvolen.

UGOLEV, B.N. (1961) Method of research of wood rheological properties at changing moisture content. *Zavodskaja laboratoria*, **27**(2), 199 – 203 (In Russian).

UGOLEV, B.N. (1976) General laws of wood deformation and rheological properties of hardwood. *Wood Science and Technology*, **10**(3): 169-181.

UGOLEV, B.N. (1986) Effect of “freezing” wood deformations at complex force and heat actions. In: *Proceedings of the 2nd International Symposium on wood rheology*, Rydzina, Poland.

UGOLEV, B.N. (2011) Nanotechnology and nanomaterials in forestry complex. Moscow : MGUL (In Russian).

UGOLEV, B.N. (2014) Wood as a natural smart material. *Wood Science and Technology*, **48**(3), 553-568.

UGOLEV, B.N., GALKIN, V.P., GORBACHEVA, G.A., KALININA, A.A. (2011) Frozen shrinkage of wood. In: *Proceedings of the 6th International symposium IUFRO -TUZVO «Wood Structure and Properties'10»*, pp.73-77, Zvolen, Slovakia.

Comparative analysis of antioxidant extractives in the bark tissues of selected wood species

T. Hofmann[1], E. Nebehaj[1], I. Eső[2], S. Fehér[2],

L. Albert[1], É. Stefanovits-Bányai[4]

[1] University of West Hungary, Institute of Chemistry, H-9400 Sopron, 4 Bajcsy-Zsilinszky str.

Email: hofmannt@emk.nyme.hu

[2,3] University of West Hungary, Institute of Wood Sciences, H-9400 Sopron, 4 Bajcsy-Zsilinszky str.

[4] Corvinus University of Budapest, Department of Applied Chemistry, H-1518 Budapest, P.O. Box 53.

Keywords: wood bark, ABTS antioxidant capacity, total phenol content, extractives

ABSTRACT

The bark of forest trees is mostly regarded as a by-product of wood processing. However, both the inner- and outer bark tissues can be a rich resource of a wide range of extractives exhibiting several beneficial effects on human health (anti-inflammatory, anti-allergic, anti-cancerogenic, etc.). It has been proven that most of these effects are based on the antioxidant properties of these extractives. Antioxidants neutralize dangerous free radicals which are produced during biotic and abiotic stress processes, thus play a major role in the defence reactions and protection of the cells in living tissues.

By extracting these compounds from the bark they could possibly be used for several different industrial purposes (wood protection agents, conservants, health-care products, nutrition supplements etc.).

The present study aims at the extraction and assessment of antioxidant compounds from the bark tissues of selected industrial wood species. Following species were considered: Pine (*Pinus sylvestris*), White poplar (*Populus alba*), Black locust (*Robinia pseudoacacia*), Sessile Oak (*Quercus petraea*). Inner and outer bark tissues were separately collected and analysed. Tissues were investigated with and without microwave pre-treatment (700 Watt, 2 min for 500 g sample), which inactivates those enzymes in the tissues which can be responsible for the oxidation of polyphenols, thus the conservation of antioxidant compounds could be achieved. Respective bark tissues were ground and sieved. The fraction between 0.2-0.63 mm mesh was used for extraction. Extraction was carried out by sonication (2x10 min, with 0.15g bark sample + 15 ml solvent). Two extraction solvents were considered for the extraction procedure: water and 4:1 methanol: water. The following parameters were measured and evaluated: total extractive content, total phenol content (Folin-Ciocalteau method), antioxidant capacity (ABTS method). All measurements were run in triplicates. Measurement results are summarized in Table 1. The following conclusions have been established:

- The outer bark of the investigated species is usually more abundant in antioxidant compounds.
- The 4:1 methanol: water mixture proved to be more efficient for the extraction especially in the case of the outer bark.
- The samples containing the highest amounts of total extractives did not always show the highest concentration of polyphenols especially in inner bark, as these tissues can contain large amounts of other types of extractives too (e.g. sugars).

- The highest total phenol and antioxidant capacity values were determined for oak and poplar.
- From total phenol and ABTS antioxidant capacity values the PAC (phenol antioxidant coefficient, calculated as the ratio ABTS (mg/g) / total phenolics (mg/g)) value can be calculated, which indicates the antioxidant efficiency of phenolic extractives in the tissues. The highest PAC values were determined for the methanolic extract of the inner bark of poplar (6.52), indicating that the extractives in these tissues are very powerful types of antioxidants. The aqueous and methanolic extracts of the microwave treated inner bark of pine (5.40, 4.80) as well as some of the black locust samples also had high PAC values (6.51 and 3.80).
- The enzyme inactivating effect of the microwave pre-treatment was not always beneficial: except for oak in all of the samples total phenol and antioxidant capacity values decreased by the use of microwave pre-treatment. Microwave pre-treatment also had diverse influence on the PAC values.

Table 1: Results of the measurements

		Total extractives [%]		Total phenols [mg quercetin/g d.w]		ABTS [mg trolox/g d.w.]		PAC [ABTS/TP]	
Species	**Tissue**	**H_2O**	**4:1 MeOH: H_2O**	**H_2O**	**4:1 MeOH: H_2O**	**H_2O**	**4:1 MeOH: H_2O**	**H_2O**	**4:1 MeOH: H_2O**
Black locust (mw)	O.b.	4.40	6.70	7.84	18.47	19.62	70.13	2.50	**3.80**
Black locust (contr.)	O.b.	6.86	7.36	12.18	29.36	29.13	**103.32**	2.39	3.52
Oak (mw)	O.b.	8.38	9.38	26.60	36.85	76.54	**121.68**	2.88	3.30
Oak (control)	O.b.	6.91	8.89	25.30	**71.57**	61.53	86.49	2.43	1.21
Pine (mw)	O.b.	4.05	8.06	8.10	15.49	22.15	50.60	2.73	3.27
Pine (control)	O.b.	2.68	6.51	6.46	16.96	19.47	37.53	3.01	2.21
Poplar (mw)	O.b.	12.09	**17.24**	28.76	**54.78**	69.12	**179.33**	2.40	3.27
Poplar (control)	O.b.	10.93	**14.90**	27.25	**49.21**	59.74	**153.85**	2.19	3.13
Black locust (mw)	I.b.	10.42	9.20	3.04	3.22	9.79	11.31	3.22	3.52
Black locust (contr.)	I.b.	11.98	**12.86**	16.36	9.90	35.62	64.38	2.18	**6.51**
Oak (mw)	I.b.	8.36	9.91	16.64	19.73	40.96	70.22	2.46	3.56
Oak (control)	I.b.	9.59	**12.48**	33.82	**46.19**	95.00	**136.50**	2.81	2.96
Pine (mw)	I.b.	2.49	4.66	0.73	2.09	3.95	10.12	**5.40**	**4.84**
Pine (control)	I.b.	9.80	12.32	10.27	16.36	17.31	53.57	1.69	3.27
Poplar (mw)	I.b.	11.90	**13.57**	7.40	4.13	15.30	26.95	2.07	**6.52**
Poplar (control)	I.b.	11.60	**17.00**	31.29	**44.05**	98.63	**148.00**	3.15	3.36

I.b.: inner bark, O.b.: outer bark, mw: using microwave pre-treatment, control: without microwave pre-treatment.

Future investigations need to be carried out for the utilization possibilities of the extracts in fields of wood-, food- and pharmaceutical industry applications and also on bark tissues of other industrially important wood species. Future analyses should also aim at optimizing bark pre-treatment before extraction.

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Reborn materials - Recycled products reused in furniture design – students' workshop

P. G. Horváth[1], M. R. Antal[2], D. Domljan[3]

[1-2]University of West Hungary, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Institute of Wood Based Products and Technologies, Bajcsy-Zs.u.4, H-9400 Sopron, Hungarygyorgy.peter.horvath@skk.nyme.hu, reka.maria.antal@skk.nyme.hu;
[3]University of Zagreb Faculty of Forestry, Department of Furniture and Wood Products, Svetosimunska 25 10000 Zagreb, Croatia, ddomljan@sumfak.hr

Keywords: student workshops, redesign, solid wood, wood materials, innovative approach, recycling, IT products

ABSTRACT

Students workshops are very good opportunity to develop students skills by usage of different materials in the design process.
Doing prototypes and small models by using recycled wood and industrial parts of machines and products, in which students can combine their creativity, intelligence, skills, conceptual thinking and other knowledge they've learned during study can produce excellent ideas and models.
One of such students' workshops, upon the name "Used cell-phones and other products reused in furniture re-design" was hold in the Institute of Wood Based Products and Technologies, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, University of West Hungary from 13rd to 15th March 2014. The workshop took part of the „REdesign+ L00147 project", Cross-border Cooperation Programme Austria - Hungary 2007-2013. The project is supported by European Regional Development Fund and the Hungarian Government. The paper describes the design process, methods and the final results of the workshop.

Workshop – step by step

In the next few chapters it is described how did students research, combine and try to find the best material both solid wood and wooden parts as well as recycled industrial parts and solutions for their conceptual ideas and how they translated ideas in functional, visual and ergonomics form, from recycled products to new prototypes.
On the first day the students (N=22) was spitted into 7 groups. Each group has the task to know the materials and the possibilities how to make the new useful products. They have started to take down the used IT products as base materials and base parts. The general base materials were IT parts and wood industrial side products. After getting information about the useable parts and technological possibilities of the workshop/woodshop, they have started to make brainstorm for making ideas/products variations. In the planning process the students have made several variation then they have chosen the optimal idea. They have used special planning methods, intuitive design techniques: *635 method, brain storming, nominal group technique (NGT), Phillips 66 method* (HEGEDŰS 1998, CHAPMAN 2013).
The guiding principle of the design process was to take into consideration the ecological design and the function analysis.
In function analysis, the product is considered as a technical-physical system. The product functions, because it consists of a number of parts and components which fulfil subfunctions and the overall function. By choosing the appropriate form and materials, students can influence the subfunctions and the overall function. The principle of function analysis is first to specify what the product should do, and then to infer from there what the parts - which are

yet to be developed - should do. The functions and subfunctions that are identified in the function analysis serve as the parameters in the morphological chart. Ideas can be search for improved function, for product components or for these combinations. Exploring ideas we have to accumulate all possibilities. We result a set of product concepts, from which after final selection the remaining product concept must work out in detail. A product concept is an approximate description of the technology, working principles and form of the product.

Figure 1: a - After brainstorming the students have started sketching and planning their products.
b - Students have started to take down the useful IT parts

On the second day the students combined and improve the concepts. Than they have selected the best one and started to make the own product. During the work the students took into consideration some of rules. These rules are: aesthetic and form design, easy to produce by the available technologies, reused materials, simplified products, daily used products, easy to assembly, correct quality, maximize compliance, design for easy of fabrication. Design for production means designing for the minimisation of production costs and times while maintaining the required quality of the product (CHANG, ET AL., 1998).

Figure 2: Reused wood panels as a lamp frame

On the last day the students have had to finish the work and make a presentation about the projects. On the show they have given a short overview about their ideas on products. After that the models was presented on an exhibition.

Figure 3: Lamps – students' works

REFERENCES

CHANG, T.-C., WYSK, R., & WANG, H.-P (1998). *Information taken from Computer-Aided Manufacturing.* Prentice Hall.
CHAPMAN A. (1995-2013). Brainstorm technique, brain storming. Download: 03. 2014, source: http://www.businessballs.com/brainstorming.htm
HEGEDŰS J. (1998). *Intuitív tervezési technikák in hungarian*, Soproni Egyetem, Sopron.

Variability of the calorific value of hybrid poplars in relation with habitation

Sz. Komán[1], S. Fehér[1], A. Benke[2], A. Borovics[2]

[1]Instititute of Wood Science– University of West Hungary
9400 Sopron, Bajcsy-Zs. U. 4. Hungary,
szabolcs.koman@skk.nyme.hu; sandor.feher@skk.nyme.hu

[2]National Agricultural Research Center – Forest Research Institute
Várkerület 30/A., 9600 Sárvár, Hungary
benkea@erti.hu; borovics@ertisarvar.hu

Keywords: poplar, biomass, energy plantation, calorific value, bark

ABSTRACT

The renewable energy sources in Hungary consist to 83% of biomass-based energy. However the purposed energy gain can only be realized by widespread energy plantations. In our country almost ¾ of the area of energy plantations consist of hybrid poplar plantations. It is known about the energetic utilization of wood, that it does not mean any excess carbon dioxide emission. Because the principal and practical conditions of plantation-like arboriculture are mainly satisfied by poplars, therefore among the species of wood plantable plantation-like they belong to the most popular ones worldwide.

During the selection of experiments for the examination of wooden biomass plantable under different habitat circumstances three (Celldömölk, Sárvár, Borjád) energetic plantations cultivated with spritting technology were assigned. 2-year-old ’I-214’ and ’Kopecky’ hybrid poplar species were subject to the inspection. The sampling of both clones was performed at three different – lower, middle and upper – heights of the stalk. Except the upper parts we have determined the calorific value both for the xylem and for the bark separately. The firing technical examinations have covered the analysis of wooden stalk of thicker, middle and thin thickness.



It can be stated for both clones, that a significant deviation regarding the calorific value cannot be experienced in accordance with the place of the xylem within the stalk. Similar observation can be made in case of the bark, however at this tree part the influencing effect of the habitation – contrary to the xylem – can be already observed. In relation of both tree parts the difference is shown already in the event of such short rotation plantations. While the calorific value of the bark in case of the ’I-214’ poplar slightly falls behind the xylem, in case of the ’Kopecky’ it is quite the contrary.

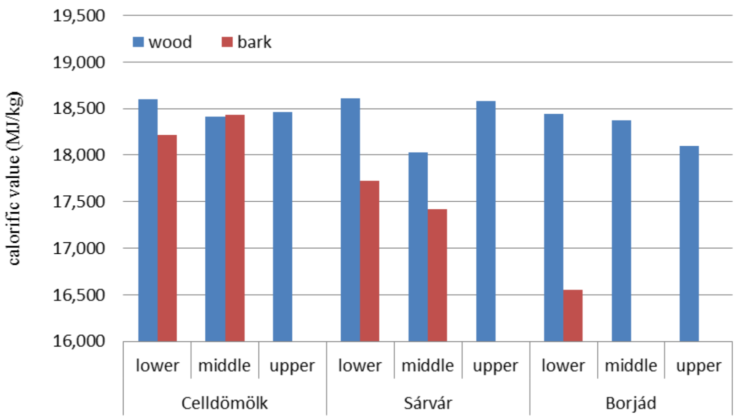


Figure 1: Calorific value of 'I-214' poplar according to habitats and the place of the sample within the stem

In case of poplar 'I-214' it can be reported in the relation of both main tree parts that the calorific value of the bark slightly falls behind that of the xylem (Fig. 1). It is especially valid for the samples coming from the Borjád and Sárvár areas. The eye-catching low value of the bark of the sample of Borjád is considerable. The calorific value of the xylem does not show significant deviation in relation of the habitats and the place within the stem. In case of the bark however higher differences can be observed among the habitats.

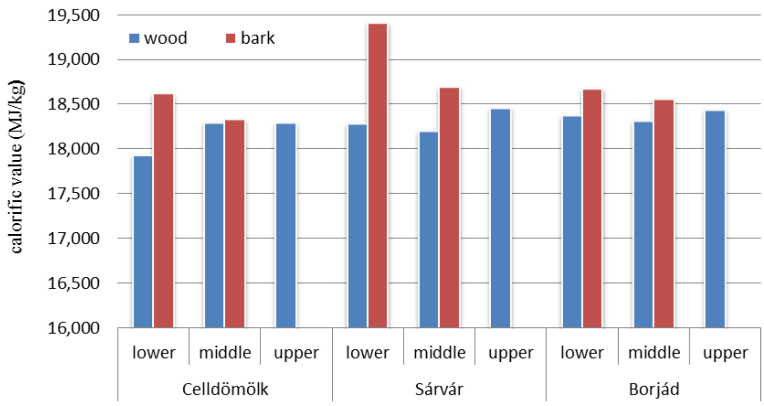


Figure 2: Calorific value of the 'Kopecky' poplar according to the habitats and the place of sample within the stem

In case of 'Kopecky' poplar the calorific value of the bark obtains mainly minimally, but a higher value related to the xylem (Fig. 2). It can be observed in case of all three habitats. The calorific value of xylem can be reported as identical independent from habitat and the place within the stem. In case of the bark the value of the sample coming from Sárvár exceeds the other two.

This study was supported by the Environment conscious energy efficient building TAMOP-4.2.2.A-11/1/KONV-2012-0068 project sponsored by the EU and European Social Foundation.

Effect of heat treatment on selected properties of oak wood

R. Lagaňa[1], R. Hrčka[1], J. Poláčik[1]

[1] Technical University in Zvolen, T. G. Masaryka 24, 96053 Zvolen, Slovakia,

lagana@tuzvo.sk, richard.hrcka@tuzvo.sk, Bc. xpolacikj@is.tuzvo.sk

Keywords: high temperature treatment, density, EMC, swelling, compression, oak.

ABSTRACT

High temperature treatment is one of common treatments used in hardwood processing. It enhances some properties, while devalues others. The aim of this study was to analyse an effect of heat treatment in oxidized atmosphere on selected physical and mechanical properties of oak wood, namely density, equilibrium moisture content (EMC), swelling, compression strength and modulus of elasticity parallel to the grain. The properties were evaluated after heat treatment at 160°C, 180°C and 200°C. Duration of the treatment was 3, 6, 9 and 12h, respectively. Results confirmed strong influence of heat treatment on the selected wood properties. EMC of treated wood decreased with the temperature of the treatment. Treatment did not influence significantly swelling coefficient. Compression strength and modulus were improved after the treatment at 180°C.

INTRODUCTION

Temperature treatment influences properties of wood. Bending strength of birch reaches its maximum after a heat treatment at 160°C and significantly drops down at 200°C. Time of treatment has a similar effect (Poncsak et al. 2006). On the other side, Yildiz et al. (2006) reported decrease of the compression strength of spruce wood only in the temperature range of 130°C to 200°C. Change of strength most probably relates to a degree of cellulose polymerisation that decreases at the high temperature (Kacikova et al. 2013). Aims of this study were to analyse an effect of heat treatment on properties of oak wood and optimize process of the treatment in dry oxidized atmosphere based on the properties changes.

MATERIALS AND METHODS

Samples of 30x30x120 mm^3 were prepared from one oak trunk (*Quercus robur*, L.). In order to homogenize sampling, the samples were randomly grouped into tested groups. Prior the treatment, the samples were oven dried at 103°C. Heat treatment was performed in an oven at temperature levels of 160°C, 180°C, 200°C and 220°C. Duration of the treatment was 3, 6, 9 and 12 hours. Altogether, 9 groups of 11 treated samples and one control group of 25 untreated samples were prepared. Oven dry density before and after treatment, EMC, compression strength and modulus parallel to the grain at standardised conditions (T=20°C, RH=65%), and a volumetric swelling coefficient were measured according to standards.

RESULTS AND DISCUSSION

During the last temperature treatment at 220 °C the samples ignited after 2.5 hours, thus this group was removed from other analysis. As it was expected, density and EMC decreased

significantly when temperature of treatment increased. Duration of the treatment was not a significant factor. The treatment at 200 °C cut down EMC to 4.06 % (change of 40% compared to untreated oak) and oven dry density to 646 kg.m^{-3} out of 733 kg.m^{-3} (Fig. 1).
A volumetric swelling coefficient was not significantly affected by a treatment. That points out to coefficient independence from temperature of a treatment. Nevertheless, lower bulk swelling after a heat treatment is caused by lower EMC only. Compression strength and modulus of elasticity parallel to the grain were the highest after the treatment at 180 °C (Fig. 2). This apparent effect was caused by lowering EMC (and consequently lowering a MC effect on mechanical properties) or/and crystallisation processes during heat treatments that was proposed by Tjeerdsma et al. (1998).

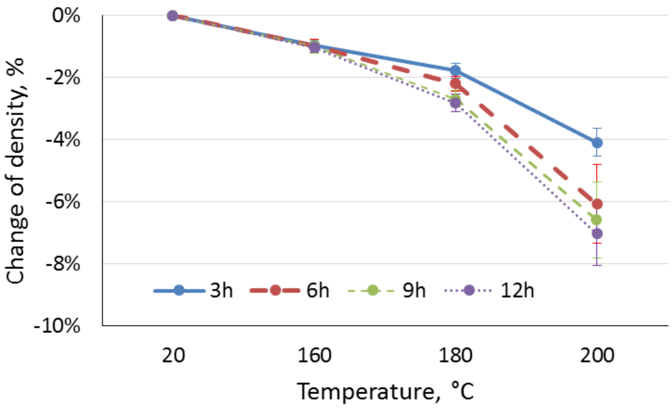


Figure 1: Change of oven dried density due to heat treatment. A bar stands for one standard deviation.

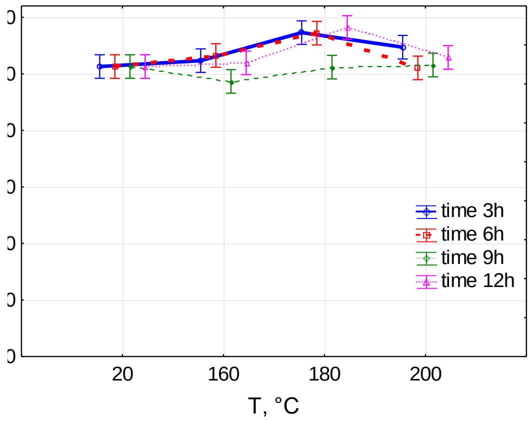


Figure 2: Compression strength of oak wood after a treatment. A bar stands for one standard deviation.

CONCLUSIONS

Based on change of properties, the optimal high temperature treatment in dry oxidised atmosphere was observed when oak wood was treated 3 hours at the temperature of 180 °C.

Acknowledgement: The research was supported by VEGA 1/0109/12.

REFERENCES

KAČÍKOVÁ, D., KAČÍK, F., ČABALOVÁ, I., ĎURKOVIČ, J. (2013) Effects of thermal treatment on chemical, mechanical and colour traits in Norway spruce wood. Bioresource Technology. 144, 669-674.

PONCSAK, S., KOCAEFE D., BOUAZARA, M., PICHETTE, A. (2006) Effect of high temperature treatment on the mechanical properties of birch (Betula papyrifera). Wood Science Technology. 40:647–663.

TJEERDSMA, B.F., BOONSTRA, M. PIZZI, A., TEKELY, P., MILITZ, H. (1998) Characterisation of thermally modified wood: molecular reasons for wood performance improvement. Holz als Roh- und Werkstoff. 56(3), 149-153.

YILDIZ, S., GEZERB, E. D., YILDIZA, U. C. (2006) Mechanical and chemical behavior of spruce wood modified by heat. Building and Environment. 41(12), 1762–1766.

Effect of fungal pre-treatment on anaerobe fermentation of bourtree (*Sambucus nigra*)

Á. Makk[1], M. Bak[2], T. Hofmann[1], R. Németh[2], T. Rétfalvi[1]

[1]Institute of Chemistry – Faculty for Forestry – [2]Institute of Wood Science –Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts

University of West Hungary, Bajcsy-Zs. u. 4., H-9400 Sopron, Hungary

tretfalvi@emk.nyme.hu

Keywords: bourtree, biodegradation, anaerobe fermentation

ABSTRACT

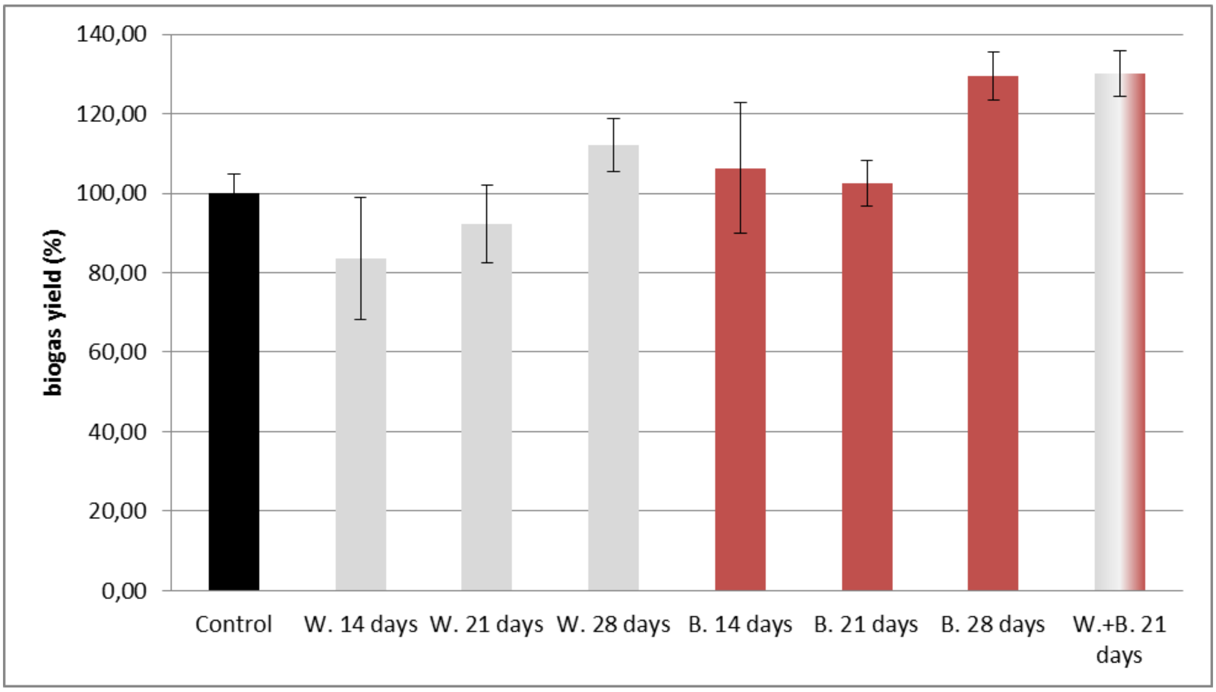
The energetic utilization of lignocellulosic materials involves several different ways. Microbial decomposition of materials with high cellulose and lignin content come off very slowly and yield low amounts of biogas. Several publications have been published on different pretreatment methods to enhance the digestibility of lignocellulosic materials (López et al. 213). Application of mechanical, thermal and chemical pretreatments have many advantageous effects but these are expensive and the toxic by-products can cause many problems.

In the present study the effect of the fungal pretreatment on biodegradability of bourtree was examined in labscale fermentation. The wood of the bourtree was chosen for the investigation because it has a general chemical composition respecting extractives and skeletal compounds, it is relatively common and industrially valueless (Atkinson and Atkinson 2002). Two different fungi species *Pleurotus ostreatus* (white-rot) and *Coniophora puteana* (brown-rot) were tested for 14-, 21- and 28-day pretreatment period (Feng et al. 2013).

After pretreatment, different physical and chemical parameters of the lignocellulose were determined for the evaluation of the degree of biodegradation. The following chemical parameters were considered for investigation: dry matter content, total soluble sugar content (Dubois method), total phenol content (Folin-Ciocalteau method), cellulose content (Kürschner-Hoffer method), total organic matter content.

Biogas yields of pretreated lignocelluloses in anaerobe fermentation were tested under thermophilic (55ºC) conditions. Chemical parameters of anaerobic sludge (acid content, COD, phosphorus content, ammonia content, organic content and dry matter content) were controlled in order to maintain the optimum fermentation conditions.

Correlations between the rate of fungal biodegradation and the measureable biogas yield have been established and evaluated.



W.-pretreated bourtree with white-rot fungi; B.-pretreated bourtree with brown-rot fungi; Control=100%, bourtree without pretreatment. Error bars indicate confidence ranges with 95% probability.

Figure 1: The effect of different pretreatment methods of bourtree wood on the biogas yield

Figure 1. summarizes the values of biogas yields indicating the effect of different fungal pretreatments. The percental values are related to untreated (control) wood samples.

It has been established that the applied chemical analytical methods are suitable for monitoring the degradation of the wood material. Pretreatments using different fungi strains and incubation times show significantly different results. In the future other fungi strains and longer incubation times will be studied.

REFERENCES

Atkinson, M.D., & Atkinson, E., (2002) *Sambucus nigra* L. British-Ecological Society. *Journal of Ecology 90, 895-923*

Feng, X., Castillo, M. del Pilar, Schnürer, A., (2013) Fungal pretreatment of straw for enhanced biogas yield *SGC Rapport 2013:279*

López, M. J., Suárez-Estrella, F., Vargas-García, M.C., López-González, J. A., Verstichel, S., Debeer, L., Wierinck, I., Moreno, J., (2013) Biodelignification of agricultural and forest wastes: Effect on anaerobic digestion. *Biomass and Biotechnology 58, 343-349*

Colour homogenisation of irregularly discoloured Robinia wood by different thermo-hygro treatments

P. Szeles, R. Németh

University of West Hungary – Institute of Wood Science
H-9400 Sopron, Bajcsy-Zs. U. 4. Hungary,

peter.szeles@skk.nyme.hu, robert.nemeth@skk.nyme.hu

Keywords: Robinia, black locust, steaming, colour change, homogenisation, iron stain

ABSTRACT

The Robinia *(Robinia pseudoacacia* L.*)* is one of the main wood species in Hungary with great industrial relevance. High share of the Robinia wood grown in Hungary is exported to different European countries. Robinia plantations cover 465.000 ha in Hungary, thus ca. 25% of the woodland area. This wood species with high natural durability (without chemical treatment) is esteemed worldwide. A newly more and more frequently detected irregularity, called by the industry "iron stain" in the wood tissue is influencing the marketability of this wood material considerably. Basically some annual rings have black discoloration.

In Sopron, at the Institute of Wood Sciences preliminary experiments were done in order to trace the biological phenomenon behind this problem. Anatomical investigations (stereo microscope) have shown that the thyloses are missing in some vessels, which is a deviation compared to the "normal" Robinia wood (in heartwood). HPLC tests showed increased extractive content (up to +70% for robinetin) in the tissues containing vessels without thyloses.

The colour of wood is very important for customers, therefore in this part of the research we focused on heat treatments (dry and steam) to diminish the discoloration. Steaming is used in the industry not only for colour-changing, but it has a beneficial effect on machining properties of the Robinia wood as well.

Colour properties are usually determined according to the CIELab colour-system. The most important influencing factors for the colour change during steaming are the temperature and the duration used. Temperature has the major role, but above 220°C the increase of the temperature has no effect on the colour (Militz 2002). The atmosphere used has also an effect on the colour change. Higher colour change occurs in the presence of air (darker colour), compared to treatments in inert atmospheres (e.g. steam, nitrogen). (Esteves et al. 2008c). It is possible to decrease the colour variability in case of turkey oak, Robinia and beech with red heartwood. (Németh et al. 2004).

The main goal of this study was to investigate the total colour difference between the parts with and without "iron stain". According to that it is possible to compare the objective (equipment) and subjective (naked eye) colour detection. If ΔE^*_{ab} is:

- *0 - 0,5 not visible with the naked eye*
- *0,5 - 1,5 slightly visible*
- *1,5 - 3,0 visible*
- *3,0 - 6,0 well visible*
- *>6,0 big colour difference*

It is well visible with the naked eye as well that the lightness of the wood decreased as a result of the heat treatment. Red hue increased while the yellow hue decreased. Higher temperature by heat treatment resulted in more homogeneous colour (beside significant loss in lightness), but in this case the pattern due to the early and latewood was diminished as well (Figure 1.). However the last can be considered as a disadvantage, because the pattern of the wood is an important aesthetical factor.

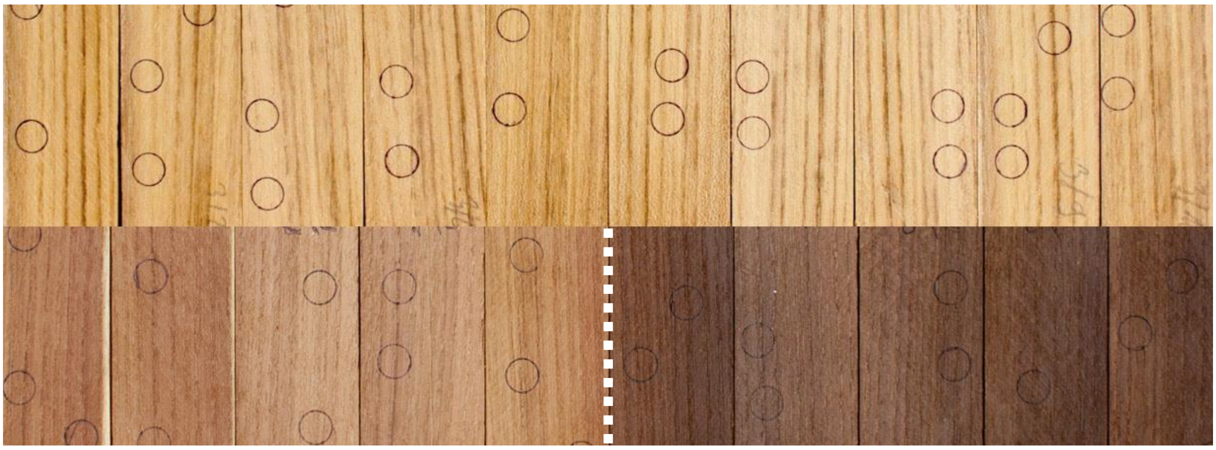


Figure 1: Comparison of untreated (upper row), and heat treated samples (bottom line, left 5 samples 160°C-1h and right 5 samples 180°C 3h)

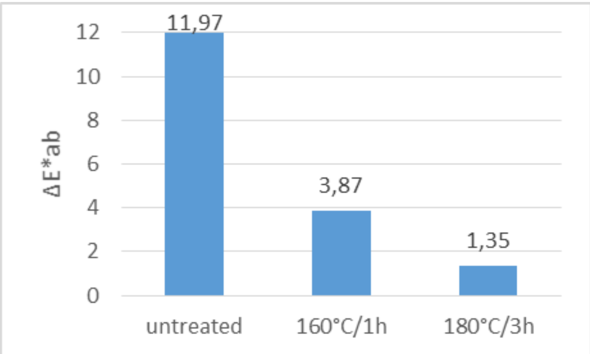


Figure 2: Colour homogenisation due to dry heat treatment

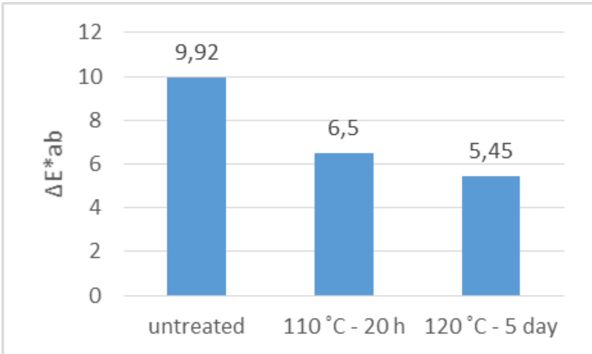


Figure 3: Colour homogenisation due to steaming

All investigated treatment variations resulted in some colour homogenisation. (Figures 2-3.). Lower colour homogenisation effect was observed in case of steaming. The decrease of the total colour difference between the discoloured and normal wood parts was attributed to the lower change of the initially darker (discoloured) parts and the general decrease of the lightness. But the total colour difference of the heat treated samples was below that of the steamed samples even if the steamed samples were darker. It is supposed that the wooden parts with "iron staining" have higher extractive content, which reacted differently in dry and steam atmospheres.

ACKNOWLEDGEMENT

This study was supported by the Project: GOP-1.1.1-11-2012 "Developing an industrialized vegetative propagation technology and the plantation model for new, extraordinary fast growing "OBELISK" Robinia varieties for high quality logs" GOP-1.1.1-11-2012-0084 project, sponsored by the European Regional Funds (EU) and the New Széchenyi Plan (Hungary).

REFERENCES

Militz, H. (2002) Heat treatment of wood: European processes and their background. In: International Research Group on Wood Preservation, IRG/WP 02-40241.
Esteves, B.; Velez Marques, A.; Domingos, L; Pereira, H. (2008c) Heat induced colour changes in pine (*Pinus pinaster*) and eucalypt (*Eucalyptus globulus*) wood. Wood science and technology, 42(5), pp. 369-384.
Németh, R.; Molnár, S.; Tolvaj, L.; Ábrahám, J. (2004) Physical and mechanical properties of steamed beech wood (with and without red heart). In: COST E44 "Wood Processing Strategy" Training course "Beech wood: From forestry to end products" Göttingen, Germany, 3-6. Nov.

Modelling the effect of orthotropic material properties on heat and moisture transport in case of spruce rafter

T. Horváth[1], Z. Pásztory[1]

[1] University of West Hungary, Innovation Center, 4 Bajcsy-Zs. Sopron, Hungary, 9400

Keywords: heat and moisture transport, orthotropic properties, rafter, spruce, FEM.

ABSTRACT

In this study, FEM modelling was performed to examine the effect of orthotropic material properties on heat and moisture transport across a spruce rafter. Results show that direction of growth rings in rafter has only minor overall effect on these processes.

INTRODUCTION

In Europe, Norway spruce is a widely favourable building material, especially in roof structures. Because of its fibrous structural tissue, thermal and moisture related properties like thermal conductivity and vapour diffusion resistance should be considered as orthotropic ones in building physics simulations. Applying the results in finite element model (FEM) modelling leads to more accurate calculations, providing more reliable estimations of heat bridge and vapour condensation.

MATERIALS AND METHODS

For stationer simulation of heat and moisture transport in a wooden rafter, 3D finite element model (FEM) of a roof fraction (without tiles) was built up in our specific program module in COMSOL® Multiphysics 4.4. Dimensions of rafter (***RT***), counter batten (***CB***) and tile batten (***TB***) were 10 cm × 15 cm, 4.5 cm × 4.5 cm and 5 cm × 3 cm (width × height), respectively. Cellulose fibre insulation (***CFI***) was inserted to the gap between ***RT***s. Spacing of ***RT***s and of ***TB***s were 90 cm and 30 cm, and one ***TB-CB*** connection node was modelled. ***TB*** was fixed to ***CB*** by a nail, and ***CB*** was fixed to ***RT*** by two additional nails with same size, each at distance of 7.5 cm from centre plane. Most of the material properties originated from WUFI®'s material database. For spruce, thermal conductivity and heat capacity data came from a recent work (SONDEREGGER ET AL. 2011) and vapour diffusion resistance data came from another one (ZILLIG AT AL. 2007). On the bottom side of model, a vapour retarder (Sd-value = 6.45 m) was fixed, and on the top side another layer (Sd-value = 0.15 m). Convective heat and vapour transfer boundary conditions were set on bottom and top side of model (T_i = 20°C, T_o = 10°C, RH_i = 45%, RH_o = 65%, α_i = 8 W/m^{2}K, α_o = 15 W/m^{2}K, $\beta_i = 6\cdot10^{-8}$ kg/msPa, $\beta_o = 2.45\cdot10^{-8}$ kg/msPa). Modelling parameters were the x and y coordinates (x_{rt} and y_{rt}) of pith of spruce stem from which ***RT*** was cut out. Coordinate system's xy and yz planes were symmetry planes of the model, xz plane was fitted to bottom side of model and x axis was parallel to the longest dimension.

RESULTS AND DISCUSSION

On bottom side of model, average and total inward heat flux, vapour energy flux, total energy flux and moisture flux were calculated. For total inward fluxes, integration was performed on ***RT*** surface and on full surface, and ratios of these values were calculated. For total energy flux this ratio can be seen in Table 1. Relative difference of the maximum and minimum values (for the selected x_{rt}, y_{rt} parameter pairs) is 5.16%, which is not significant. In the case of inward heat flux, vapour energy flux and moisture flux, relative differences are 5.15%, 6.83% and 2.76%, respectively. Relative differences of maximum and minimum values of average inward fluxes on bottom side are 1.38%, 0.25%, 1.38% and 0.10% for heat, vapour energy, total energy and moisture fluxes, respectively. From these results, it seems that orthotropic material properties of spruce have minor effect on heat and moisture transfer in cross-sectional direction of rafter.

Table 1: Ratio of total inward energy flux across rafter's surface to that of full surface (bottom side) [%]

x_{rt} [cm][a]	y_{rt} [cm][b]							
	-10	**-5**	**0**	**5**	**10**	**15**	**20**	**25**
-20	20.57	20.39	20.25	20.20	20.27	20.41	20.58	20.73
-15	20.72	20.51	20.30	20.24	20.34	20.53	20.73	20.88
-10	20.92	20.70	20.41	20.32	20.48	20.72	20.92	21.04
-5	21.13	21.00	20.66	20.59	20.78	20.99	21.13	21.19
0	21.23	21.16	20.85	20.82	20.98	21.14	21.22	21.24

[a] x coordinate of spruce stem's pith, [b] y coordinate of spruce stem's pith (see details in text)

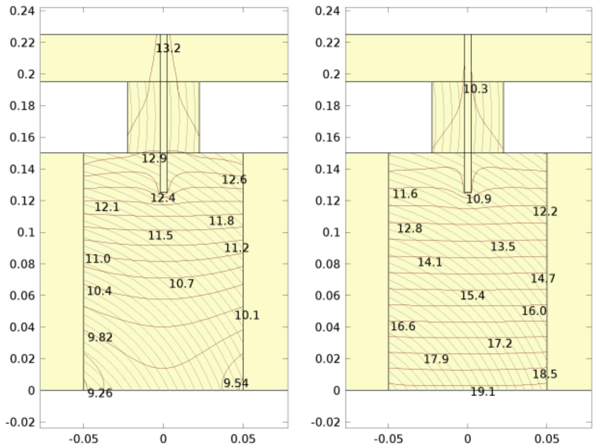


Figure 1: Moisture content [%] (left) and temperature [°C] (right) distribution of spruce elements in the xy symmetry plane of the model, x_{rt} = -10 cm and y_{rt} = -5 cm (growth rings are drawn with grey contours)

ACKNOWLEDGEMENTS

This study was supported by the Environment conscious energy efficient building TAMOP-4.2.2.A–11/1/KONV-2012-0068 project sponsored by the EU and European Social Foundation.

REFERENCES

SONDEREGGER, W., HERING, S. AND NIEMZ, P. (2011) Thermal behaviour of Norway spruce and European beech in and between the principal anatomical directions. *Holzforschung*, **65**(3), 369-375.

ZILLIG, W., DEROME, D., CARMELIET, J.E. AND DIEPENS, J.F.L. (2007) Mesoscopic modeling of vapor transport in wood tangential and radial direction. In: *Proceedings of the 10th Conference on the Thermal Performance of the Exterior Envelopes of Whole Buildings*, 2-7 December 2007, Clearwater Beach, Florida, USA, ASHRAE.

SESSION I
STRUCTURE & PROPERTIES

Interplay of density, moisture content and specimen size on static and dynamic determination of stiffness properties of beech wood

Ž. Gorišek[1*], S. Pervan[2], M. Trop[1], A. Straže[1]

[1]University of Ljubljana, Biotechnical Faculty, Department of Wood Science and Technology
Rožna dolina, C. VIII/34, SI 1000 Ljubljana Slovenia
University of Zagreb, Faculty for Forestry, Svetošimunska 21, Zagreb, Croatia
*zeljko.gorisek@bf.uni-lj.si

Keywords: stiffness, nondestructive testing, density, moisture content, beech wood

ABSTRACT

The influence of density, moisture content and specimen size on modulus of elasticity of beech wood was analyzed. Oriented and conditioned wood specimens were examined at 3-point static bending at same span to depth ratio to determine the static modulus of elasticity and free-free flexural vibration tests were carried out to determine the dynamic modulus of elasticity in longitudinal and transversal direction. A strong correlation was approved among static and dynamic modulus of elasticity. The highest impact on modulus of elasticity had density, but slightly worse was the impact of moisture content. Size of specimen did not show significant influence. A multiple regression model for predicting modulus of elasticity of beech was compared with the model of spruce.
In particular for construction purposes the mechanical characterization of wood properties is considered as the most important for the evaluation of its quality and the possibility of its end use. The objectives of various research projects have in principle purpose of reducing the uncertainty of wood characteristics as influenced by its biological nature. Furthermore, on high variability and heterogeneity of mechanical properties of wood have significant influenced also great number of diverse factors, therefore, followed a question of reliability of different methods for the determination of mechanical characterization of wood.
The objective of this study is to examine the reliability of vibration testing for evaluation of the dynamic mechanical properties of beech wood. The aim of the study is also to establish the correlation, frequency range and impact of density, moisture content and specimen size on modulus of elasticity of beech wood and to set up an appropriate regression model.
Selected dried beech wood (*Fagus sylvatica* L.) boards were conditioned and six oriented specimens of different size were carefully sawed from each board. After equilibrating specimens at three humidity levels (RH1 = 33 %; RH2 = 65 % and RH3 = 87%), vibration tests were carried out for determinate modulus of elasticity in longitudinal (E_{dyn_L}) and transversal (E_{dyn_T}) direction and static (E_s) modulus of elasticity was proceeded.
Flexural vibrational method gave acceptable correlation values between dynamic modulus of elasticity and modulus of elasticity determined at static bending.
The best and the same time the simplest dependence of modulus of elasticity from beech wood density was obtained by linear regression (Fig. 1). The impact of density was significant in all tests and correlation coefficient was in all cases relatively good. Predictably, the values were lower and with smaller dependence at higher moisture content of wood.
A little less expected was a dependence of elastic modulus from moisture content. In general, we confirmed that the modulus of elasticity decreases with moisture content, regardless of the methods, but the correlation and impact is not so high as with density (Fig. 2).
With multiple regression analyze we get a relatively simple linear model for predicting modulus of elasticity depending on density and moisture content. As the specimen size did not show a significant impact in all three methods, it is not included in the model. The comparison between

regression models of beech and spruce showed remarkably similar correlation with a little stronger influence of density and like the same influence of moisture content.

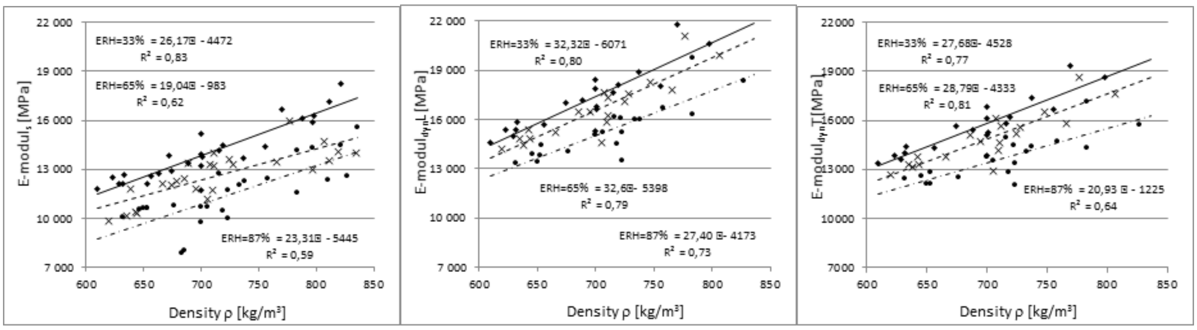


***Fig. 1** Dependence of a/static, b/ longitudinal dynamic and c/ transfers dynamic modulus of elasticity from beech wood density at three equilibrium states (♦ - RH= 33%, × - RH = 65 % and ● - RH = 87%).*

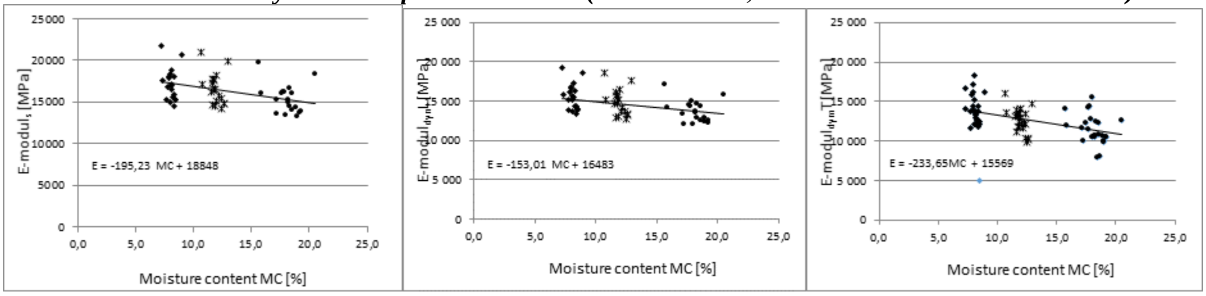


***Fig. 2** Dependence of a/static, b/ longitudinal dynamic and c/ transfers dynamic modulus of elasticity from the moisture content of beech wood.*

Beech	**Spruce**
$E_s = 22{,}44 \times \rho - 270{,}65 \times MC - 4{,}95$	$E_s = 31{,}00 \times \rho - 244{,}78 \times MC - 17{,}15$
$E_{dynL} = 27{,}72 \times \rho - 242{,}55 \times MC - 8{,}20$	$E_{dynL} = 37{,}23 \times \rho - 222{,}82 \times MC + 27{,}90$
$E_{dynT} = 25{,}24 \times \rho - 235{,}83 \times MC + 1{,}42$	$E_{dynT} = 33{,}09 \times \rho - 193{,}47 \times MC + 10{,}29$

CONCLUSIONS

Relatively strong correlation exists between static and dynamic modulus of elasticity whereas dynamic vibrational method, especially longitudinal, overestimate the stiffness measured by static bending test. The deviation between static and dynamic modulus of elasticity are caused by contributable effect of shear stress at 3-point bending and compression deformations at supports. Density has greater influence on modulus of elasticity as moisture content but the effect of both parameters are significant. Dimensions of specimens did not show a significant impact on modulus of elasticity probably because only clear and oriented wood was used in the research. Therefore, it is very little impact of anomalous wood structures like, grain deviation, knots, reaction wood on wood properties. Modulus of elasticity of beech can be well predicted by multiple regression model with liner impact of density and moisture content.

The work is part of the research project V4-1419 "Rational use of hardwoods with a focus on beech wood" supported by the Ministry of Agriculture and the Environment of the Republic of Slovenia (MKO) and the Slovenian Research Agency (ARRS),

Swelling of subfossil oak under different conditions

J. Baar[1], O. Nevrlý[2]

[1] Department of Wood Science – Mendel University in Brno,
Zemědělská 1, 613 00 Brno, Czech Republic,
jan.baar@mendelu.cz

[2] Department of Wood Science – Mendel University in Brno,
Zemědělská 1, 613 00 Brno, Czech Republic,
xnevrly@node.mendelu.cz

Keywords: subfossil oak, swelling, equilibrium moisture content

ABSTRACT

Subfossil wood is unfossilized wood which has been deposited in rivers, swamps or moraine sediments for hundreds or thousands of years. A number of complicated physical and chemical processes take place during the deposition under these specific conditions. Besides the colour darkening, physical and mechanical properties change as well. When this wood is dried without special treatment, extensive dimensional changes and distortions can occur.

With regard to dimensional changes, there are considerable differences found when the values of living and subfossil wood are compared. HORSKÝ AND REINPRECHT (1986), ROWELL AND BARBOUR (1990) and KOLÁŘ AND RYBNÍČEK (2010) stated the subfossil oak shows approximately twofold values of tangential swelling in comparison with living oak, which limited its use. On the other hand, GRABNER AND TERS (2009) reported lower values ranging between 3.8% and 7.4%, which was partially explained by not perfect anatomical orientation of samples. Despite some wood properties deterioration and technological problems, subfossil wood is a demanded and valuable material, mainly for its dark shade and unusual appearance.

Wood from three trunks from different time periods (A: 1131–804 B.C., B: 208 B.C. –137 A.D., C: after 1018 A.D.) was used. The samples were dried carefully until constant weight was achieved. Then the samples were stored under standard climate (20°C, 65%) and full saturated air (20°C, 100%) for several weeks during which the moisture content was stabilized. The equilibrium moisture content (φ = 65% and 100%) of subfossil oak wood was measured and compared with living oak wood. The swelling under saturated air condition was measured and then the samples were stored in water for 20 days. After this time the swelling in liquid water was determined.

The average measured values of equilibrium moisture content varied between 13.7 and 14.2% for standard climate and between 26.0 and 27.3% for fully saturated air (see Fig. 1). The values of subfossil oak were comparable with living oak. The tangential swelling of subfossil oak was higher in comparison with living oak by 1.3–4.8% (see Fig. 2) when the samples were stored in saturated air. The increase in affinity to water is attributed to a higher amount of the amorphous part of cellulose in subfossil oak (GRABNER AND TERS 2009) or freer bonding sites in cellulose due to hydrolysis of hemicelluloses (KOLÁŘ ET AL. 2014). When the samples are exposed to liquid water, the swelling is higher than in saturated air and almost double in comparison with living oak (see Fig. 2). This increase in swelling is probably due to leaching of degradation products or inorganic compounds stored in wood during the fossilization process. The chemical analysis of leaching water will be the next step in order to find out which compounds are responsible for the distinct swelling if subfossil oak is immersed in water.

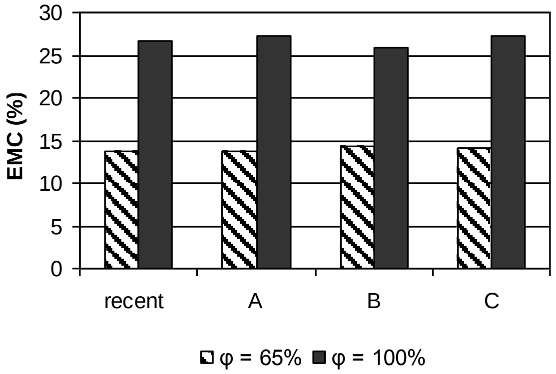


Figure 1: Equilibrium moisture content of living and subfossil oak

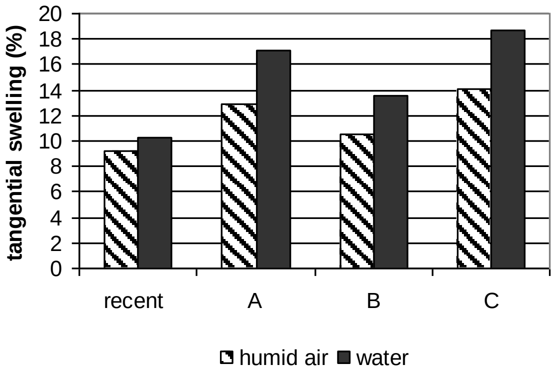


Figure 2: Tangential swelling of living and subfossil oak under different conditions

REFERENCES

GRABNER, M., TERS, T. (2009) *The suitability of sub fossil oak wood to build pipe bowls*. [cited 20 July 2014]. Available from: *http://www.pfeifen-prammer.com/files/pfeifen_prammer/pdf/Morta.pdf*

HORSKÝ, D., REINPRECHT, L. (1986) *Študia subfosilneho duboveho dreva*. Vysoka škola lesnicka a drevarska, Zvolen.

KOLÁŘ, T., RYBNÍČEK, M. (2010) *Physical and mechanical properties of subfossil oak (Quercus sp.) wood.* Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 58(4), 123-133

KOLÁŘ, T., RYBNÍČEK, M., STŘELCOVÁ, M., HEDBÁVNÝ, J., VÍT, J. (2014) *The changes in chemical composition and properties of subfossil oak deposited in Holocene sediments*. Wood Research, 59(1), 149-166

ROWELL, R. M., BARBOUR, R. J. (1990) *Archaeological Wood: Properties, Chemistry, and Preservation*. American Chemical Society, Washington, DC.

Importance of green wood strength

F. Divos[1]

[1] University of West Hungary, Bajcsy Zsilinszky 4, 9400 Sopron Hungary, ferenc.divos@skk.nyme.hu

Keywords: Tree stability, pulling test, green wood strength, elastic limit

ABSTRACT

Wood strength is a basic material property. We have strength data for almost all species, important for forest product industry. The relevant standard set the conditions of the strength determination in laboratory conditions, EN 338, EN 408, ASTM D2555. The reference wood moisture content is 12%. Strength properties of wood depend on moisture content. Increase of moisture content leads to lower the strength. EN 384 gives rules for moisture content adjustment in the range of 10-18 % moisture content range. Trees are naturally grown wooden structures. For trees the moisture content adjustment is not possible, because its moisture content is far above the fiber saturation point. Stability of trees is important in urban areas and nearby roads. People like trees, want to keep as long as possible, but old trees are source of risk as well. Arborists are working for trees and keeping tree related risk on an acceptable low level. One of the arborist task is the stability evaluation. The process of tree evaluation always starts with visual investigation. If necessary continues with some instrument supported tree evaluation method. One of these methods is the pulling test. Wind load is substituted by static pulling, while the elastic deformation of the tree trunk is recorded. To calculate the safety factor of the tree, among of other data the strength parameter of the given wood species is necessary. Unfortunately wood strength data in green condition is rather limited. Only the "Stuttgart table of wood strength" is available, containing 45 species published by Wessoly (1998). Goal of this paper is to express the importance of green wood strength.

PULLING TEST PROCEDURE

Most of the cases the compression strength is the limiting properties for trees. The load on tree is compression load from the self-weight and bending from the wind load. The resulting compression load is higher than tension load. In case of leaning trees with asymmetric crone, the shear strength can be the limiting factor, but we neglect this case. The applied pulling test setup for tree trunk safety evaluation is shown on figure 1. - including the evaluation principle. Wind load is substituted by static pulling, while the elastic deformation of the tree trunk is recorded. Till the tree deformation in fiber direction is less than the elastic limit, the tree is in a safe condition. The elastic limit in compression for wet wood in fiber direction is in the region of 3-7 ‰., according to Wessoly L (1998).

In the test procedure we record the elastic deformation: $\boldsymbol{\varepsilon=\Delta L/L}$ versus the applied force $\boldsymbol{F}$. Test points fit to a line, see figure 1, top right corner. Extrapolating the line till the elastic limit $\varepsilon_{\mathrm{lim}}$, we get the critical force: $\boldsymbol{F_c}$. Using the critical force and the applied geometry data like – rope height on tree, anchor tree distance shown on figure 1. – provide us the critical turning moment $\boldsymbol{M_c}$ of the tree. Of course this information is relevant only the section of the tree trunk, where the elastometer is located. If the tree trunk at the location of the elastometer contains large decay or hollow, the elastic deformation is increasing and the critical force is decreasing, relative to the intact case. Detecting large internal decay is possible by pulling test; even the defect is not visible from outside.

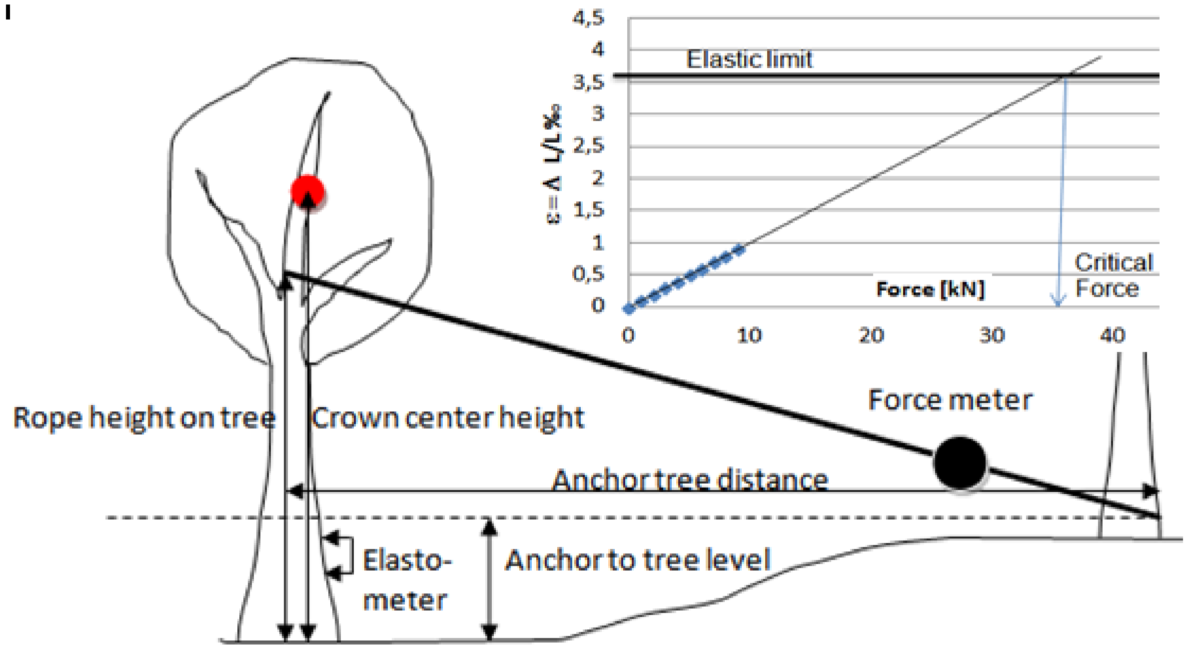


Figure 1: The pulling test setup for testing tree trunk.
The evaluation principle is shown on the top right corner.

The safety factor **SF** of a tree is given by the ratio between the critical turning moment and the turning moment related to the wind M_w load in case of strong wind: **SF** = M_c / M_w .The method of wind load calculation is given in EN 1991: (Eurocode 1) Actions on structures.

CONCLUSION

For reliable tree evaluation we need green wood strength data, especially compression strength in fiber direction. The elastic limit plays important role in the three evaluations practice. We need data for many-many wood species available in urban are. Basically arborists have no laboratory dedicated for strength determination. Wood science laboratories may play important role in generating more data in the future.

REFERENCES

Wessoly L., Erb M: 1998. Handbuch der Baumstatik und Baumkontrolle. Patzer Verlag, Berlin

Brudi, E. 2002. Trees and Statics: An introduction. Arborist News: 28-33.

ASTM D2555 - 06(2011): Standard Practice for Establishing Clear Wood Strength Values

EN 338: Structural timber — Strength classes

EN 408: Structural timber and glued laminated timber — Determination of some physical and mechanical properties

EN 1991: (Eurocode 1) Actions on structures

Analysis of phenolic components in Sweet chestnut (*Castanea sativa* Mill.) heartwood

S. Eichhorn[1], T. Hofmann[2], L. Tolvaj[3], R. Németh[4], F. Hapla[1]

[1] Georg-August-Universität Göttingen, Abteilung Holzbiologie & Holzprodukte, D-37077 Göttingen, Büsgenweg 4

[2] University of West Hungary, Institute of Chemistry, H-9400 Sopron, 4 Bajcsy-Zsilinszky str.

[3] University of West Hungary, Department of Physics, H-9400 Sopron, 4 Bajcsy-Zsilinszky str.

[4] University of West Hungary, Institute of Wood Sciences, H-9400 Sopron, 4 Bajcsy-Zsilinszky str.

Keywords: Sweet chestnut, heartwood, phenolic components, Folin-Ciocalteu assay

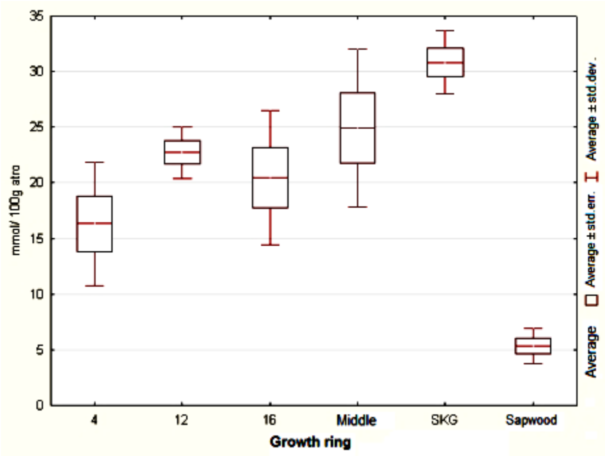
ABSTRACT

Despite the background of climate change, Sweet chestnut (*Castanea sativa* Mill.) gets more and more important. Its excellent wood properties are becoming increasingly into the focus of economic usage. Having high natural durability, the heartwood of Sweet chestnut is predestinated for outdoor-use. The phenolic extractives protect the heartwood against wood decaying fungi and allow an application without chemical wood protection. Thereby, Sweet chestnut makes an important contribution to the environment. The present investigation deals with the analysis of the total phenol content in Sweet chestnut heartwood. The goal of the research was to determine and compare the radial distribution of the amount of phenolic extractives in the heartwood of selected sample trees, originating from the same region (Region Haardt, in Rheinland Pfalz/D) but from three different locations with different stand conditions. Five stems were randomly chosen from each location for the investigation. Total phenolic contents were measured by means of UV-VIS spectrometry (Folin-Ciocalteu assay) and by FT-IR analysis.

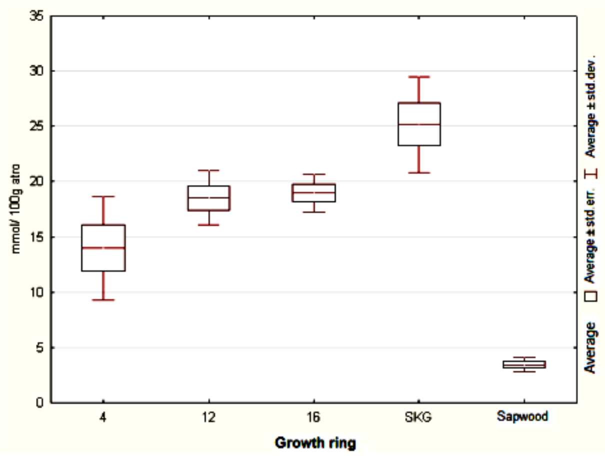
From the stems disk were cut and then wood specimens were separated from the middle strip of stem disks. To demonstrate the distribution of the phenolic components along the radial gradient, the specimens from the middle strips were taken by a defined pattern from the pith up to the sapwood. The latewood-zone of defined growth rings was investigated by FT-IR spectroscopy and after appropriate extraction and sample clean-up by the Folin-Ciocalteu assay.

By means of FT-IR spectroscopy no clear results in relation to the research goal could be determined. The photometric analysis allowed the assessment of the radial distribution of the total phenol content. With regard to the distribution, an increase of the content of the phenolic components was determined in the Sweet chestnut heartwood, from the pith up to the sapwood-heartwood-boundary. Compared to the heartwood, significantly lower amounts of phenols could be determined the sapwood.

By carrying out preliminary HPLC-MS/MS analyses the major phenolic compounds of Sweet chestnut heartwood have been separated and identified. The separation method can be further developed to be suitable for quantitative analysis of the identified compounds too. By the means of correlations between wood durability parameters and the concentration of individual phenolic extractives/total phenol content and using further FT-IR measurements the quality of Sweet chestnut heartwood could be assessed in the future.



location A



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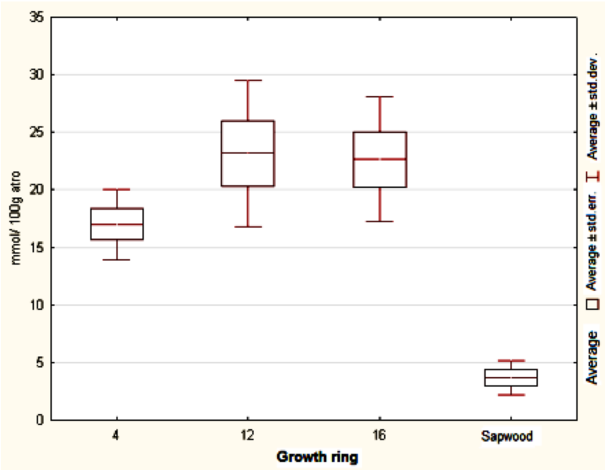

location E

Figure 1: **Radial distribution of total phenol content in stems (n=5) from different locations.**

ACKNOWLEDGEMENTS

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SESSION II
STRUCTURE & PROPERTIES

Physical and mechanical properties of common ash wood (*Fraxinus excelsior* L.)

P. Niemz, S. Clauss, C. Pescatore, F. Michel

Swiss Federal Institute of Technology (ETH Zurich), Institute for Building Materials, Wood Physics, Steffano-Franscini-Platz 3, CH-8093 Zürich
niemzp@ethz.ch

Keywords: Ash wood, mechanical properties, physical properties, moisture content, orthotropy.

ABSTRACT

Nowadays hardwood is increasingly used in timber construction, partly as substitute of softwood members or in combination with softwood. Hardwood shows principally similar orthotropic behaviour to softwood. However, the magnitudes and the ratios of the mechanical parameters between the three anatomical directions differ and depend strongly on the individual microstructure of the species. The aim of this study is to characterize the orthotropic mechanical behaviour of common ash (*Fraxinus excelsior* L.) under varying equilibrium wood moisture conditions.
An FE-calculation of total strain (incl. internal stresses, warping) needs following parameters

$$\varepsilon_{tot}=\varepsilon_{el}+\varepsilon_{\omega}+\varepsilon_{\omega\sigma}+\varepsilon_{pl} \quad (1)$$

where ε_{tot} is the total strain, ε_{el} the elastic strain, ε_{ω} the moisture induced strain, $\varepsilon_{\omega\sigma}$ the strain induced by creep and mechanosorption and ε_{pl} the plastic strain.

All these parameters are required in the 3 main directions longitudinal (L), radial (R) and tangential (T) and are moisture and time dependent. In the present work elastic constants in tension, compression and strength were tested. Also elastic parameters by means of sound propagation (longitudinal and transversal waves) were determined. Table 1 shows for instance the dynamic shear modulus, moisture dependent and in different directions. Furthermore, important physical properties of ash, such as differential swelling ratio, water absorption coefficient, water vapour resistance and thermal conductivity were obtained within this study.

Tab. 1: Results of shear modulus (G) from dynamic tests by an Epoch XT device (Olympus) with a Staveley S-0104 transducer (1 MHz) for transverse waves; n = 20; ρ_{12} = 0.59-0.61g/cm^3; ω = moisture content; () = coefficient of variation in %.

ω [%]		G_{LR} (MPa)		G_{LT} (MPa)		G_{RT} (MPa)	
8.2	(1.6)	1283	(2.8)	1050	(16.9)	357	(8.5)
13.4	(5.0)	1177	(6.5)	812	(6.9)	382	(17.9)
17.5	(2.6)	1031	(10.4)	806	(3.9)	263	(6.5)
18.8	(4.6)	964	(5.5)	780	(6.6)	246	(9.9)

As a result, a dataset of selected moisture dependent elastic and strength parameters for different load types and orientations were generated (see Clauss et al. 2014a, Clauss et al. 2014b). As examples, Fig. 1 and 2 show the influence of moisture content on modulus of elasticity (MOE) and Poisson ratio.

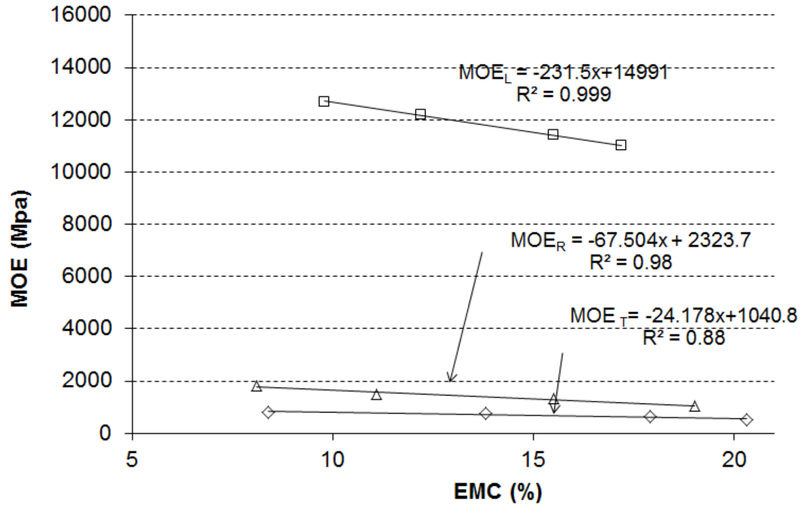

Figure 1: MOE in tension dependent on equilibrium moisture content (EMC) for ash wood

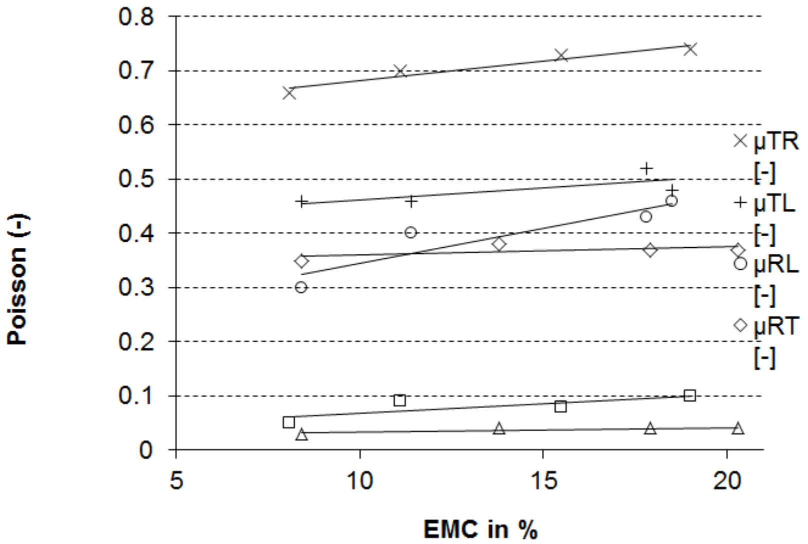

Figure 2: Poisson ratios dependent on equilibrium moisture content (EMC) for ash wood

REFERENCES

CLAUSS, S., MICHEL, F. NIEMZ, P. (2014a) Physical and mechanical properties of common ash (*Fraxinus excelsior* L.). Wood Research (submitted)

CLAUSS, S., PESCATORE, C., NIEMZ, P. (2014b) Anisotropic properties of common ash (*Fraxinus excelsior* L.). Holzforschung (online first)

Comparing the effects of two heat treatment methods in vacuum on some mechanical properties of Beech wood

B. Bazyar

Department of Wood and Paper Science and Technology, College of Agriculture and Natural Resources , Science and Research Branch,
Islamic Azad University, Tehran, Iran

bazyar@srbiau.ac.ir

Keywords: linseed oil, Heat treatment, Mechanical properties

ABSTRACT

The heat treatment may result in changes in some of the physical and mechanical properties of wood. In this study, beech wood (*Fagus orientalis*) was heat treated at 180 C° for a 6 hour period with two methods; heat treatment in a vacuum oven and heat treatment with hot linseed oil in a vacuum tank. During this research, some mechanical properties of wood containing MOE, MOR, impact strength and compression strength perpendicular to the grain were studied. After delignification of wood flour, the holocellulose content of beech wood, before and after modification, was measured.

For thermal modification, the sapwood of beech wood was selected. The first groups of samples were oil heat treated in double decker tank and heated for 6 hours after the core of samples were reached to 180C°. The second groups of samples were placed in vacuum oven for 6 hours at 180C°. In both methods -0.5 bar pressure was used. After treatment, conditioning the samples at room temperature for 45 days were done, then mechanical tests were applied.

The measured mechanical properties of treated and untreated samples are given in table1.

Table 1: Mechanical properties of treated and untreated samples

Samples	**MOE** (MPa)	**MOR** (MPa)	**Impact strength** (KJ/m^2)	**Compression strength** perpendicular to the grain (KN)
Control	7587.5	71.75	28	21.75
Oil Heat Treated	7234.8	65.45	22.45	23.05
Heat Treated in Oven	6268.5	58.85	16.98	19.78

The impact strength results of control samples were found 28 KJ/m^2, while impact strength results of oil heat treated and in a vacuum oven heated samples were 22.45 and 16.98 KJ/m^2 respectively. It means impact strength of wood after heat treatments were reduced about 20 and 39.9 percent in oil heat treatment and oven heat treatment, respectively.

Statistical analysis and DMRT grouping showed that oil heat treatment had not significant effect on MOE, MOR and compression strength perpendicular to the grain, but heat treatment in oven caused an important reduction in these properties. After heating the wood in oven 18, 17.4 and 9.2 % reduction in MOE, MOR and compression strength perpendicular to the grain were occurred. It must be noted that after oil heat treatment in vacuum, compression strength perpendicular to the grain of beech wood was increased but this increment was not statistically significant. It was observed in thermally treated wood, mechanical properties

started to reduce when the temperature of treatment reaching 180C°. It can be related to holocellulose reduction after heat treatment.
The results of this research showed that the holocellulose content of control, oil heat treated and oven heat treated samples were about 73%, 65.7% and 59.6%. It means the decrease rate of holocellulose content were reduced about 10% and 18% after oil and oven heat treatment respectively. These reductions are related to thermal degradation of wood, decomposition of wood components and losses of wood substances specially hemicellulose after heating. It was mentioned that hemicellulose content of wood after heat treatment at 180C° to 260C°decreased significantly. Also, it was reported that holocellulose content of beech wood after heat treatment at 240 C° decreased to 50%.
The results of this study also showed better mechanical properties of oil heat treated wood compared to oven heat treated ones. This can be related to the fact, oil heat treatment has a lesser effect on holocellulose reduction than the second method.

REFERENCES

Boonstra, M. J., & Tjeerdsma, B. (2005). Chemical Analysis of Heat Treated Softwoods. *Journal of Holz als Roh-und Werkstoff, 64*(3), 204-211.

Hill, C. A. S. (2006). *Wood Modification: Chemical, Thermal and Other Processes*. John Wiley & Sons, Ltd. England.

Inari, G. N., Petrissans, M., & Gerdin, P. (2007). Chemical Reactivity of Heat-treated Wood. *Journal of Wood Science and Technology, 41*(2), 157-168.

Rapp, A. O., & Sailer, M. (2000, November). Heat treatment of wood in Germany-state of the art. In *Proceedings of the seminar on production of heat treated wood in Europe* (Vol. 20, p. 2000).

Razak, W., Izyan, K., Hanim, A. R., Othman, S., Aminuddin, M., & Affendy, H. (2011). Effects of hot oil treatment on colour and chemical changes in 15-year-old Acacia hybrid. *Journal of Tropical Forest Science*, 42-50.

Varied extract gain of 'Accelerate *fex*IKA extraction' and influences of different process parameters

P. Sablík, P. Rademacher

Mendel University in Brno, Faculty of Forestry and Wood Technology, Department of Wood Science
Address: Zemědělská 3, 613 00 Brno, Czech Republic
sablik.pavel@email.cz

Keywords: *Robinia pseudoacacia* L., soluble substances, phenolic compounds, heartwood

ABSTRACT

In the presented work, first results of extraction techniques of *Robinia pseudoacacia* L. heartwood by *fex*IKA advanced methodology were studied to show how the process is influenced by various input settings. Three main parameters were evaluated in this study. Firstly type of solvent used, then possible temperature, which can be reached during extraction process and lastly quality of used material. Study is focusing on yield and amount of phenolic compounds under different process parameters.

It is well known that heartwood of some wood species growing in the temperate zone and also a lot of tropical wood species show higher natural resistance against attack by wood degrading fungi and/or insects. Their higher natural durability is assigned to the presence of specific extractive compounds, in the first place (NZOKOU AND KAMDEM 2003).

Heartwood extracts from a wide range of plant and tree species show activity against fungi and insects and many of them can potentially serve as wood protection agents alone or in combination. In addition to the chemical composition of extractives, heartwood durability is related to the amount and distribution of extractives within wood tissues, and this knowledge can serve as a helpful guide in developing extractive based wood protection systems (SINGH AND SINGH 2012). The idea to utilize compounds extracted from corporation process waste products from various high durable wood species as an antifungal agent was already applied in the past (KARTAL ET AL. 2006).

The high durability of *Robinia pseudoacacia* L. heartwood is assign to the presence of two main attendant chemical compounds (flavonoids): first of them is the dihydroflavonol dihydrorobenitin (3,7,3',4',5'pentahydroxydihydroflavonol) and the corresponding flavonol robinetin (3,7,3',4',5'pentahydroxyflavonol), which both inhibit fungal growth.

Very first step of analysis of wood chemical compounds and also most time consuming, is extraction of wood matter. To increase speed and decrease costs of extraction process, it's possible to use, instead of standard Soxhlet apparatus, advanced *fex*IKA method. This equipment, thanks to lower amount of solvent necessary for the process and to process set up itself, could decrease time for determination of the extractive content in the sample to half with 90% extraction efficiency compared with Soxhlet apparatus (SCHWANNINGER AND HINTERSTOISSER 2012).

Experimental data shows promising results for the future investigation of chemicals, extracted by *fex*IKA method, and their application to improve the native durability of wood. The yield of extraction was evaluated for different particle sizes, ground to pass a 4.0mm, 2.0mm, 1.0mm, 0.5mm screen and wood powder (particle size ≤ 5µm). Due to significant influences of solvent polarity on composition of extracted compounds nine solvents with polarity index from 0.0 (cyclohexane) to 9.0 (water) were included into investigation (see results in Fig.1). Due to native character of chemical compounds, also influence of temperature was

investigated and samples from heat treated *Robinia pseudoacacia* L. were extracted and evaluated.
Including all these factors, it was possible to get deeper information about the extraction process itself and demonstrate the variation of quantitative amount of extractive compounds, possible to obtain from heartwood of *Robinia pseudoacacia* L.

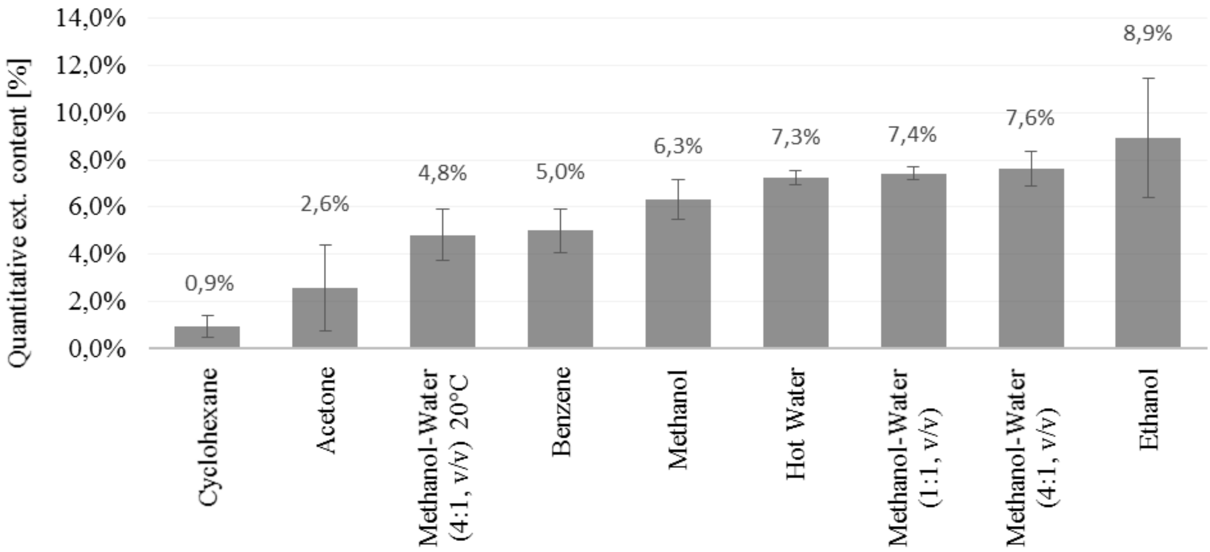

Figure 1: Quantitative extraction results obtained with using solvents with different polarity, in percentage to dry wood of Robinia pseudoacacia* L. *heartwood; screen 0.5mm; 110% solvent/mixture boiling temperature; n=10

REFERENCES

KARTAL S.N., HWANG W.J., IMAMURA Y. AND SEKINE Y. (2006) Effect of essential oil compounds and plant extracts on decay and termite resistance of wood. *Holz als Roh- und Werkstoff*, 64:455-461.

NZOKOU P. AND KAMDEM D.P. (2003) Fungal decay resistance of non-durable aspen wood treated with extractives from African padauk (Pterocarpus soyauxii). *Journal of Tropical Forest Products*, 9 (1 & 2): 125-133.

SINGH T. AND SINGH A.P. (2012) A review on natural products as wood protectant. *Wood Sci Technol*, DOI 10.1007/s00226-011-0558-5.

SCHWANNINGER M. AND HINTERSTOISSER B. (2002) Comparison of the classical wood extraction method using a Soxhlet apparatus with an advanced extraction method. *Holz als Roh- und Werkstoff*, 60:343-346

Machine grain angle determination on six European hardwoods

P. Schlotzhauer[1], L. Emmerich[2], H. Militz[3], S. Bollmus[4]

[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, lukas.emmerich@stud.uni-goettingen.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, sbollmu@gwdg.de

[4] 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: grain angle determination, field strength measurement, hardwood

ABSTRACT

New approaches to silviculture call for a maximum increase of biodiversity in forests through the creation of mixed forests. This contradicts the consumption of lumber, which in Germany is currently made up of about 75% coniferous lumber (Seintsch & Weimar 2012). Against this background, it will be necessary to use hardwood more extensively to meet future demands.
Therefore the aim of the FNR research project 'New markets and applications for native hardwood species' is to develop deciduous lumber-based products and make those, in close cooperation with partners from the forestry and timber industry, available to the consumer. The project focuses on the use of hardwood for 1) structural purposes, 2) exterior uses and 3) wood based composites.
As example here the work of the work package 1) structural purposes will be sketched. The aim of this work package is the use of deciduous lumber for glulam. The focus is set on the development of sorting criteria for the strength grading of glulam and single lamellas. One main criterion influencing the main strength and MOE values of timber is the grain angle. When increasing the angle between wood grain and loading direction, the strengths and MOEs decrease considerably. Up to now a reliable machine for grain angle determination of deciduous lumber does not exist. Thus, one of the goals of this investigation is to evaluate the suitability of the electric field strength measurement for grain angle determination. This is done for the six European hardwood species *Acer spp.* L., *Betula pendula* R., *Fagus sylvatica* L., *Fraxinus excelsior* L., *Quercus spp.* L. and *Tilia spp.* L..
For each of the six hardwood species one specimen of the size 98,4x100x30mm³ is evaluated. The hand-held device Model 511 Grain Angle Meter of the company Metriguard Inc. (USA) is used to determine grain angles via field strength measurements in a 5x5mm² grid on radial/tangential surfaces. Assuming that wood splits along the fibers (grain), the specimens are split subsequently in a 20x5mm² grid. The splitting angles are measured visually. The values of the 5x5mm² grid (electric field strength measurement) are interpolated and compared with the 20x5mm² grid of the specimen splitting.
The obtained data show only weak to moderate correlations between the field strength measurements and reference angles attained through splitting the wood (Table 1). Between the 6 hardwood species clear differences can be detected.

Table 1: Correlation coefficients (R^2) of grain angles determined via electric field strength measurement and splitting.

Species	R^2	R^2 (after systematic correction)
Acer spp. L.	0,10	0,19
Betula pendula R.	0,30	0,67
Fagus sylvatica L.	0,45	0,79
Quercus spp. L.	0,14	0,49
Fraxinus excelsior L.	0,44	0,84
Tilia spp. L.	0,16	0,33

For all species especially in the border areas the angle differences between both measurement systems are deviatingly high. The same applies for areas with knots (Fig. 1). A systematic correction of the border areas, where the measuring range of the Grain Angle Meter overlaps the specimen's edges, improves the correlations significantly (McDonald et al. 1987). However striking differences between the 6 hardwoods are still recognizable.

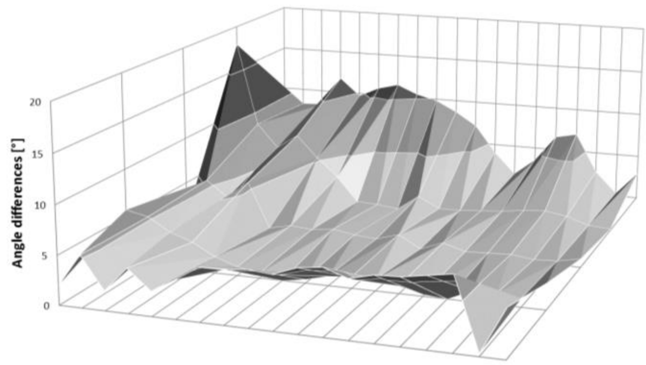

Figure 1: **3-D surface diagram of the angle differences [°] between the two different measurement systems (electric field strength vs. splitting) for the bottom surface of *Betula pendula* R.. The left back corner shows angle measurement differences between 5 and 20 degrees due to a knot.**

Both measurement systems contain sources of error. Those should be the subject of further investigations. Looking ahead a microscopic detection should prove that the employed splitting method generates a precise splitting along the fibers. Furthermore the two systems should be compared with the tracheid effect scanning (laser dots) employed for machine grain angle determination on softwood boards.

REFERENCES

MCDONALD, K., CRAMER, S. AND BENDTSEN, B. (1987) Research progress in modeling tensile strength of lumber from localized slope of grain. In: *Proceedings of the 6th Nondestructive testing of wood symposium*. Pullman, Washington, pp. 113-123. Washington State University, Pullman.

SEINTSCH, B. AND WEIMAR, H. (2012) Actual situation and future perspectives for supply and demand of hardwood in Germany. In: *The 5th Conference on Hardwood Research and Utilisation in Europe*, eds. R. Németh and A. Teischinger. Sopron, Hungary, pp. 301-312. University of West Hungary Press, Sopron.

The branch wood of poplar (*Populus* x *canadensis* MOENCH): anatomical and histometric characteristics

J. H. Blohm[1], D. Dujesiefken[2], U. Schmitt[3]

[1]Thünen Institute of Wood Research, Leuschnerstraße 91 d, 21031 Hamburg, Germany, jan.blohm@ti.bund.de

[2]Institute of Arboriculture, Brookkehre 60, 21029 Hamburg, Germany, dirk.dujesiefken@institut-fuer-baumpflege.de

[3] Thünen Institute of Wood Research, Leuschnerstraße 91 d, 21031 Hamburg, Germany, uwe.schmitt@ti.bund.de

Keywords: poplar, branch wood, anatomy**,** histometry, tension wood

ABSTRACT

Poplar (*Populus* x *canadensis* MOENCH) trees are fast growing trees which are used for manifold purposes. Its stem wood was therefore well analysed for its anatomical and histometrical details. However, poplar branch wood attracted minor attention and there are much less details available on the anatomy. The present paper deals with anatomical and histometric details of six branches grown in northern Germany which varied in terms of diameter, age, angle and orientation. By means of light microscopy, histometric parameters were determined for upper and lower branch sides. Also the occurrence of tension wood was recorded for the analysed growth rings. Histometric evaluation focussed on differences between upper and lower branch sides as well as in different distances to the stem (BLOHM 2011). The probability of significant differences between upper and lower branch sides increased with the distance to the stem. In cases of such differences, cell dimensions of lower branch sides were always greater than of upper branch sides (Table 1).

Table 1: Comparison of upper and lower branch sides: histometric parameters at different distances to stem.

Distance to the stem [m]	Branch sides	Fibre length [µm]	Double fibre wall thickness [µm]	Tangential vessel diameter [µm]	Vessel area [%]	Ray height [µm]	Number of rays per mm [-]
0.3	upper	642 ± 162	5.3 ± 1.1	42.1 ± 10.8	33.2 ± 4.1	215 ± 72.5	13 ± 2
	lower	623 ± 188	6.2 ± 1.1^{c}	40.5 ± 11.3	28.5 ± 5.2	217 ± 60.1	13 ± 2
0.5	upper	710 ± 185	6.4 ± 1.5	43.2 ± 14.1	31 ± 3.8	203 ± 52.3	9 ± 2
	lower	686 ± 174	6.9 ± 1.9^{d}	45.1 ± 14	31 ± 3.8	207 ± 59.0	10 ± 1
1.0	upper	689 ± 184	6.3 ± 1.5	42.4 ± 11.8	28.7 ± 7.3	-	-
	lower	732 ± 208^{s}	6.5 ± 1.4	50.9 ± 13.6^{d}	30.1 ± 4.2	-	-
2.0	upper	876 ± 153	5.7 ± 1.4	47 ± 12.7	34.4 ± 7.1	-	-
	lower	914 ± 168^{d}	6.2 ± 1.3^{c}	49.4 ± 14.4	34.2 ± 5.8	-	-
3.0	upper	755 ± 157	5.7 ± 1.4	39.2 ± 11.8	29.6 ± 7.6	175 ± 53.5	12 ± 3
	lower	786 ± 173^{s}	6.0 ± 1.2^{d}	46.3 ± 14.5^{d}	31.2 ± 5.6	206 ± 71.4^{c}	12 ± 2

^{s}significant ($0.05 > p \geq 0.01$), ^{d}decisive ($0.01 > p \geq 0.001$), ^{c}conclusive ($0.001 > p$) difference

While fibre length showed no significant difference between upper and lower branch sides near the stem, fibres of the lower branch sides were longer with increasing distance to the stem. Intra-side comparison of fibre lengths in different distances to the stem revealed a maximum fibre length for both sides at two metres distance to the stem. Fibre walls were thicker on the lower branch sides at all distances to the stem except at one metre. Side-wise evaluation revealed a maximum fibre wall thickness for both sides at half metre distance to the stem. When comparing heartwood and sapwood, the latter showed larger fibre dimensions. Tangential vessel diameters differed between upper and lower branch sides at one and three metres distance to the stem. A comparison of vessel diameters at different distances to the stem showed no significant differences on both branch sides. Ray height was rather uniform with the exception of a significant difference at three metres distance to the stem. Similarly, the number of rays per millimetre was determined as not differing between both sides.

In growth rings with a relatively high amount of vessels, four branches did only contain sparse gelatinous fibres in upper branch sides. However, gelatinous fibres were found in lower branch sides of five branches (Figure 2) as already described for both poplar and some other hardwood species by MATHEW (2003), FISHER AND STEVENSON (1981) and TERRELL (1953).

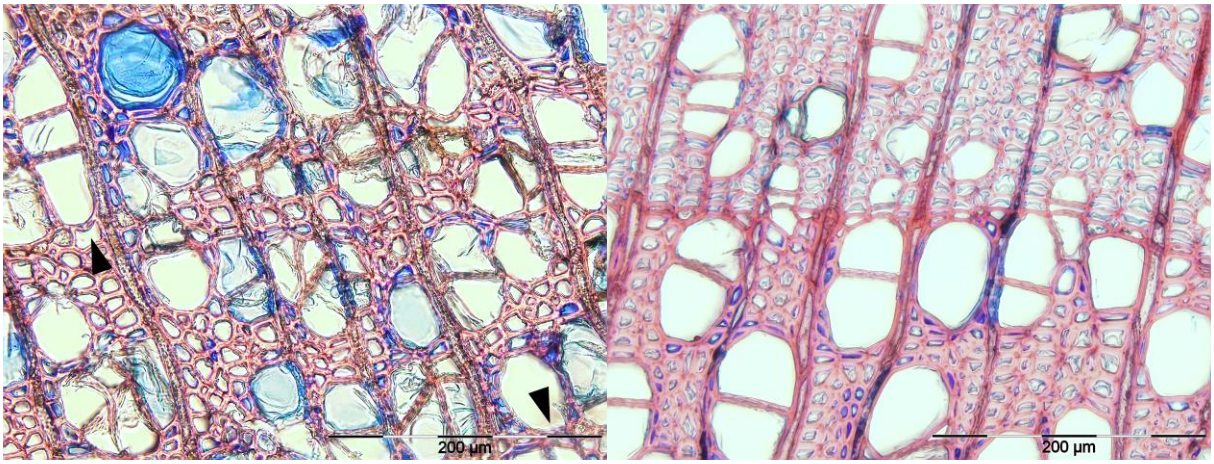

Figure 2: Narrow growth ring (borders indicated by arrowheads) without gelatinous fibres in an upper branch side (left), frequent occurrence of gelatinous fibres in lower branch side (right).

These anatomical and histometric results clearly show that branch wood is distinctly different to stem wood, already in tissue portions rather close to the stem. Additionally, the inhomogeneity especially between upper and lower branch sides became evident.

REFERENCES

BLOHM, J. H. (2011): Holzanatomische Untersuchungen an Ästen der Hybridpappel (*Populus* x *canadensis* MOENCH). Diploma thesis. Hamburg University, Hamburg.

FISHER, J. B.; STEVENSON, J. W. (1981): Occurrence of reaction wood in branches of dicotyledons and its role in tree architecture. *Botanical Gazette* **142** (1) 82–95.

MATHEW, F. (2003): Structural studies on tension wood of *Hevea brasiliensis* (Para Rubber) with special reference to clonal variability. Dissertation. Mahatma Gandhi University, Kottayam, India.

TERRELL, B. Z. (1953): Distribution of tension wood and its relation to longitudinal shrinkage in aspen. *Materiae vegetabiles* **1** (3) 288–299.

SESSION III
STRUCTURE & PROPERTIES

Revealing the variation of lignin and hemicelluloses microdistribution in poplar cell wall during hydrothermal pretreatment

Jing Ma[1], Xun Zhang[1], Feng Xu[1]*

[1] Beijing Key Laboratory of Lignocellulosic Chemistry, – Beijing Forestry University, Tsinghua East Road 35, 100083 Beijing, China,

* xfx315@bjfu.edu.cn

Keywords: lignin, hemicelluloses, hydrothermal pretreatment, immune-gold labeling

ABSTRACT

Hydrothermal pretreatment (HTP) using water as an only solvent is a very promising option to overcome the recalcitrance of cell wall, which caused the removal of lignin and hemicelluloses from the cell wall (PU ET AL. 2013). The information about the variations of ultrastructural localization of lignin and hemicelluloses in the cell wall during HTP is little known but is essential to understanding the process of HTP-induced biomass deconstruction.
In our current research, the changes in lignin and hemicelluloses microdistribution of poplar cell wall pretreated with liquid hot water at 170 °C for 5, 10, 20, 30, and 40 min were investigated. The HTP caused the alterations of lignin and hemicelluloses microdistribution in a chemical-dependent manner. Confocal Raman microscopy (CRM) images exhibited that the loss of lignin concentration in the middle layer of secondary wall (S2 layer) was more than that in the compound middle lamella (CML) after 30 min of pretreatment (**Fig. 1**), whereas transmission electron microscopy (TEM) in combination with immuno-gold labeling demonstrated that the decline of xylans labelling density in the S2 layer was less than that in the CML and the outer layer of secondary wall (S1 layer) (**Fig. 2**). In addition, the little reduction of mannans labelling density across the cell wall was occurred. These results suggested that during HTP the removal of lignin was mostly from the S2 layer, while the removal of hemicelluloses mainly resulted from the removal of xylans from the CML and S1 layer. The current study is the first report of the ultrastructural location of dissolved xylans following HTP. These findings expected to provide some useful reference for understanding the mechanism of pretreatment on overcoming lignocellulosic biomass recalcitrance.

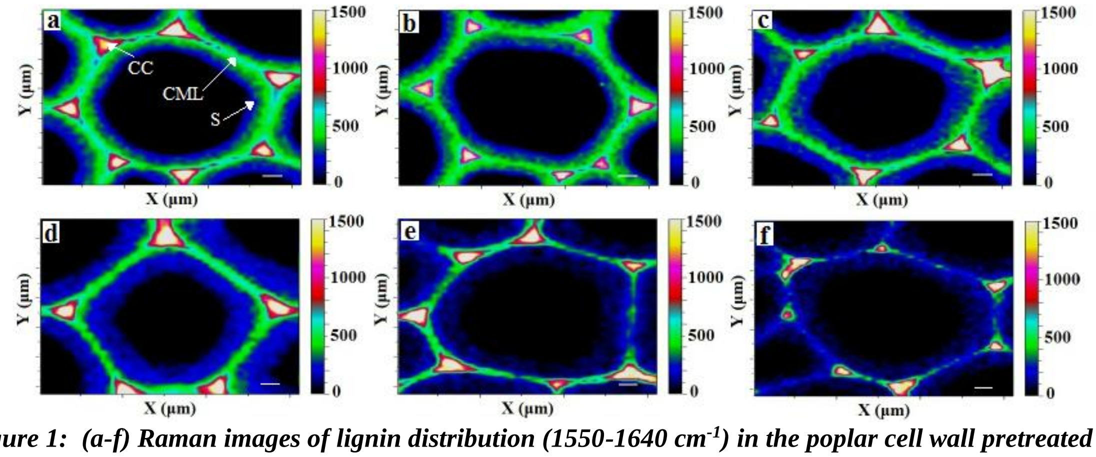

***Figure 1:** (a-f) Raman images of lignin distribution (1550-1640 cm^{-1}) in the poplar cell wall pretreated with liquid hot water at 170 °C for 0, 5, 10, 20, 30, 40 min respectively. The intensity scale is shown to the right.*

Bright whit/yellow locations represent high concentration of component. Dark blue/black regions signify correspondingly very low concentration. Scale bars: 2 µm.

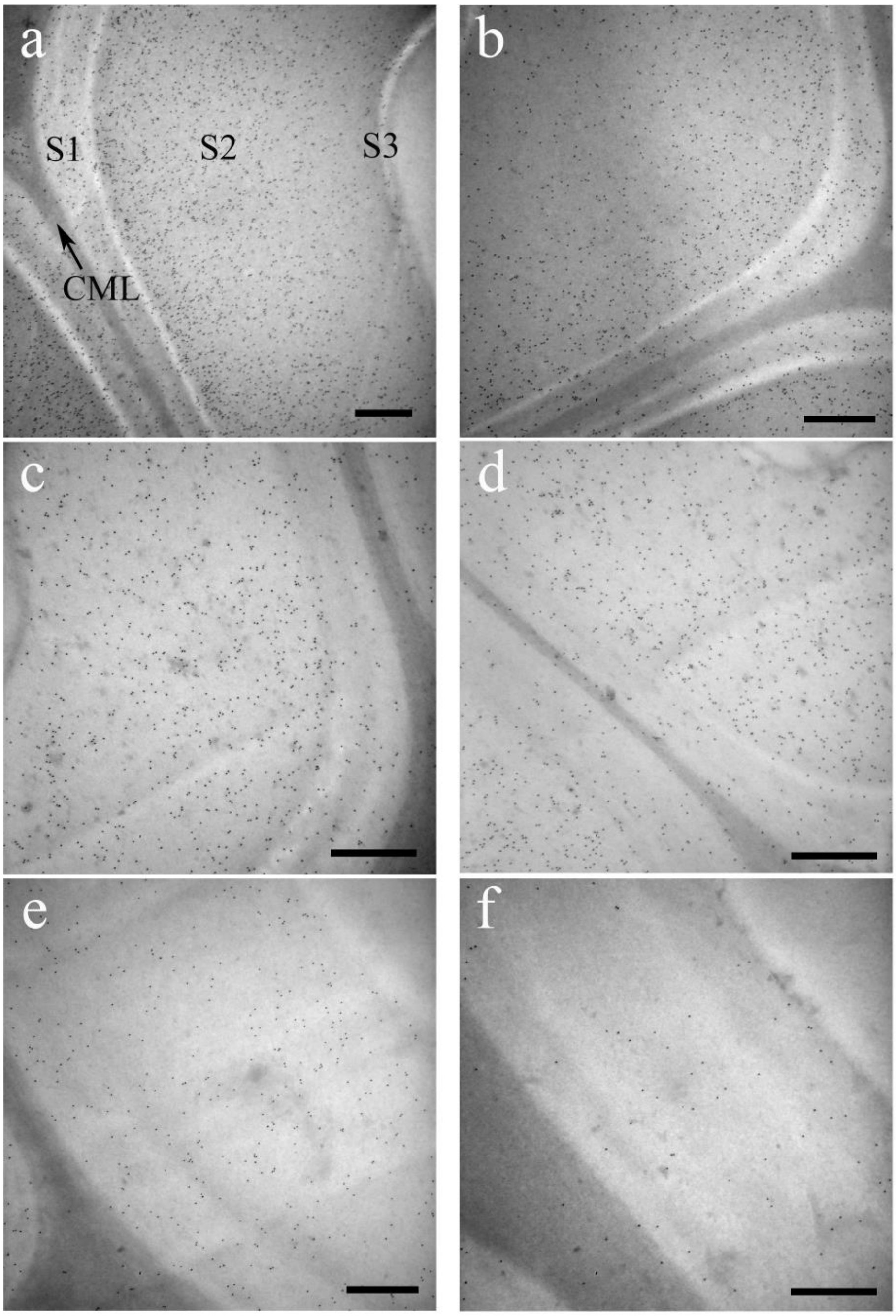

Figure 2: (a-f) Immunogold localization of xylan in the poplar cell wall pretreated with liquid hot water at 170 °C for 0, 5, 10, 20, 30, 40 min respectively. Scale bars: 500 nm.

REFERENCES

PU, Y., HU, F., HUANG, F., DAVISON, B. H., & RAGAUSKAS, A. J. (2013). ASSESSING THE MOLECULAR STRUCTURE BASIS FOR BIOMASS RECALCITRANCE DURING DILUTE ACID AND HYDROTHERMAL PRETREATMENTS. BIOTECHNOL BIOFUELS, 6(1), 1-13.

Roles of signal transduction substances in pathological or traumatic heartwood formation in deciduous oak trees.

F. Yamamoto[1], B. Moungsrimuangdee[2],

[1]Faculty of Agriculture, Tottori University, Koyama, Tottori 680-8553, Japan,
fukuju@muses.tottori-u.ac.jp

[2]Bodhivijjalaya College, Srinakharinwirot University, Thailand,
boon2523@yahoo.com

Keywords: ethylene, jasmonic acid, *Platypus quercivorus*, *Quercus*, *Raffaelea quercivora*, salicylic acid, sapwood discoloration

ABSTRACT

Mechanisms of pathological or traumatic heartwood formation in deciduous oak trees infected with a fungus named *Raffaelea quercivola* disseminated by ambrosia beetles, *Platypus quercivorus*, were studied in Japan. Ethylene production in living and dying stems of *Quercus serrata* trees infected with *R. quercivola* was compared to that in non-attacked stems. The density of attacks by ambrosia beetles was extremely high at the stem base (Fig. 1).High levels of ethylene production occurred in stem segments of a survived tree compared with those in non-attacked or killed trees (Fig. 2). Earlywood vessels occluded with tyloses significantly increased in the survived tree compared with the non-attacked tree (Fig. 3). Current-year wood located close to the cambial region had high ethylene production ability, unlike the inner sapwood or intermediate wood in the survived tree.

Ethrel (Et), methyl jasmonate (MJ), methyl salicylate (MS) or sodium salicylate (NS), and mixed combinations of these chemicals were horizontally injected into stems of matured trees or applied to stem surfaces of seedlings to induce defense responses in *Quercus* species. The combination of MJ and Et (MJ+Et) induced the greatest discoloration among all treatments (Fig. 4). Sodium salicylate (NS) or methyl salicylate (MS) alone increased the discolored area to a lesser degree than did MJ, but defensive responses were obviously more accelerated when the former were added to the latter in the combination treatments. In particular, induced discoloration was noticeably achieved following MJ or Et combined with NS rather than as individual treatments. In contrast, neither salicylate appeared to promote discoloration when combined with the MJ+Et treatment.

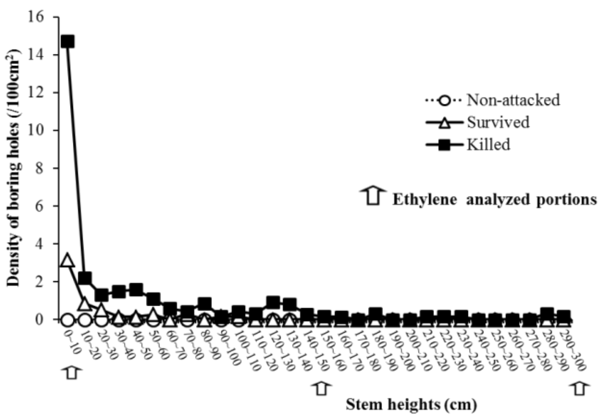

Fig. 1: Attack density of P. quercivorus beetles on stems of the non- attacked, survived, and killed Q. serrata trees at various heights from 0 to 300 cm above the ground.

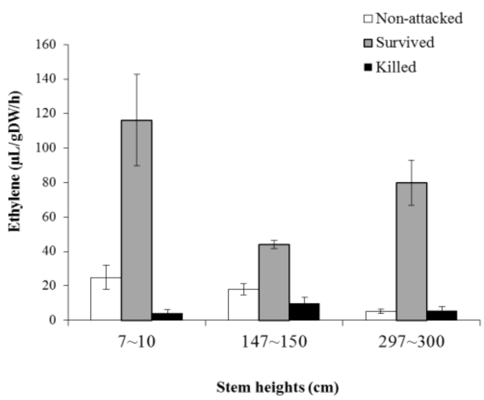

Fig. 2. Ethylene production from segments of the current-year wood in the non-attacked, survived, and killed Q. serrata trees at three different stem heights. Error bars indicate SE.

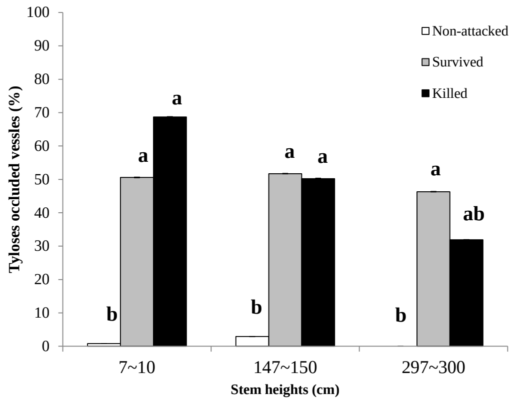

Fig. 3. Rate of tylose formation in earlywood vessels of the current-year wood of the non-attacked, survived, and killed Q. serrata trees at three different stem heights. Error bars indicate SE.

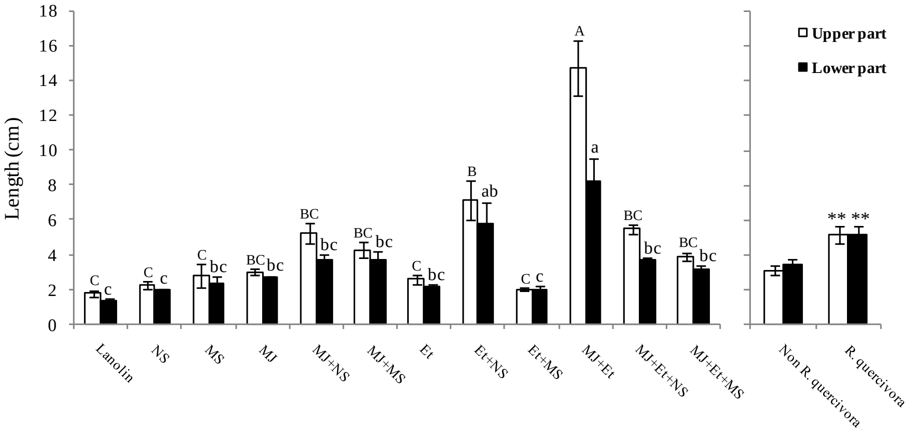

Fig. 4. Axial sapwood discoloration length of Q. serrata four months after wounding through the application of chemicals and with fungal inoculation in upper and lower parts of the treated wound. – Et: ethrel; MJ: methyl jasmonate; MS: methyl salicylate; NS: sodium salicylate. – Data are represented as mean and ± SE of 18 replications for each treatment. – Different letters in each column indicate significant differences (P < 0.05) using Scheffe's test. – ** = difference significant at P < 0.01.

REFERENCES

Boontida Moungsrimuangdee, Hiroyuki Moriwaki, Masanori Nakayama, Shintaro Nishigaki and Fukuju Yamamoto.(2011.3). Effects of injection of Ethrel, methyl jasmonate, and salicylates and *Raffaelea quercivora* inoculation on sapwood discoloration in *Quercus serrata*. IAWA Journal, Vol. 32 (1), 41-53.

Boontida Moungsrimuangdee, Minako Tanaka, Naoya O-hara and Fukuju Yamamoto. 2011.7. Ethylene production from xylem and tylose formation in earlywood vessels of ambrosia beetle-attacked stems in *Quercus serrata* trees. Tree and Forest Health. 15 (3), 89-96.

Highly stressed composite materials of small cross-sections of European ash and fibre-reinforced plastics

M. Zauer[1], A. Spickenheuer[2], G. Heinrich[2], A. Wagenführ[1]

[1] Technische Universität Dresden – Institute of Wood and Paper Technology, Marschnerstraße 32, 01307 Dresden, Germany, mario.zauer@tu-dresden.de

[2] Leibniz-Institut für Polymerforschung Dresden e.V., Hohe Straße 6, 01069 Dresden, Germany

Keywords: composite materials, fibre-reinforced plastics, small cross-sections of hardwood

ABSTRACT

Statically and dynamically highly stressed small cross-sections of hardwood used for therapy and sports equipment, musical instruments, ladders and other work equipment, needs a high degree of resistance to dynamic loads and at the same time a cross-section which is as small as possible. This derives on the one hand from the requirements for lower self-weights. In addition, it is of primary importance that ergonomically pleasant and safe handling should be ensured. What is crucial here however is that not only the high values of the load-bearing capacities but also the safety of these values since an incalculable material failure such as could occur in dynamically highly stressed work or leisure equipment could cause serious injuries to users.

Wood is an anisotropic and inhomogeneous material whose strength values are subject to a wide scatter due to fluctuations in raw density and also structural defects such as knots and oblique fibrous nature. To improve load-bearing and deformation behaviour or reliability, specific reinforcement measures are eminently suitable which use high-strength materials such as fibre-reinforced plastics (FRP) (Zauer ET AL. 2007-A). Here the major proportion of the cross-section is still wood. Of vital importance here is the consciously reinforcement of structural flaws which may not have been detected but which can thus be relieved.

The main objective of our investigations was the development of a suitable technology, an on-step-process (Zauer ET AL. 2007-B), for the reinforcement of small cross-section of European ash with fibre-reinforced plastics by means of resin injection as well as resin infusion. In this on-step-process, the FRP is produced directly on the wood cross-section and simultaneously bonded with the wood (Fig.1).

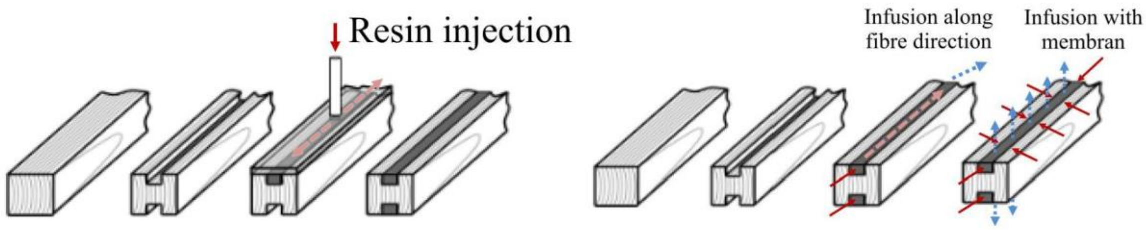

***Figure 1:** Principle sketches of the injection process (left) and of the infusion process (right)*

The dimensions of the samples were 20 mm x 20 mm x 360 mm (radial x tangential x longitudinal). The FRP were arranged on both the tension side and the pressure side of the samples. The total fraction of the FRP cross-section relative to the wood cross-section was 3 % and the fibre volume fraction of the FRP was 35 %. As reinforcing fibre carbon fibres

(CF) high tenacity (HT) were used and the matrix material were both different epoxy resin EP L + EPH L (LL) and Greenepoxy 55 + GP 505 (G). 4-point bending tests according to DIN 52186 were conducted in dependence of the climatic state of the samples: 20°C and 45%, 65%, 85% relative humidity (RH). The resulting average equilibrium moisture contents (EMC) were 7.9%, 11.5%, 19.8%. Fig. 2 shows the average modulus of rupture (MOR) and average modulus of elasticity (MOE) of the unreinforced ash cross-sections and the reinforced ash cross-sections in dependence of the climatic state of the samples. The coefficient of variation of all results within a series was max. 12%.

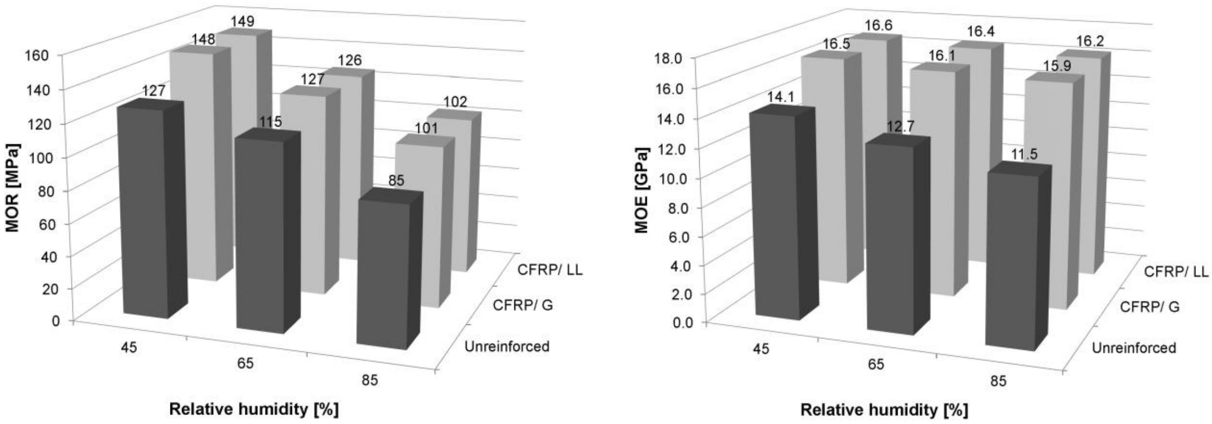

***Figure 2:** Average values tested by 4-point bending test: MOR (left) and MOE (right) in dependence of the climatic state of the samples*

The results clearly show that MOR and MOE increase significantly owing to the reinforcements. In the case of the samples conditioned at 20°C and 85% RH, MOR increase about 20% and MOE increase about 40%. As expected MOR and MOE of the unreinforced samples decrease with increasing of RH and thus increasing of EMC. Likewise, MOR of the reinforced samples decreases with increasing of RH. However, the climatic state has for the reinforced samples a quite small influence of the values of MOE. That means, the reinforcements of the samples, in our case with a total fraction of 3% relative of the wood cross-section, led to an almost independence of EMC in terms of MOE (homogenization).

REFERENCES

DIN 52186 (1978) Prüfung mit Holz: Biegeversuch. German Institute for Standardization

ZAUER, M., WAGENFÜHR, A. AND GOTTLÖBER, C. (2007-A) Verstärkungsmöglichkeiten an kleinen Vollholzholzquerschnitten mittels faserverstärkter Kunststoffe. Teil 1: Verbundwerkstoffe auf der Basis Vollholz und CFK. *holztechnologie*, 48(3), 38-43.

ZAUER, M., WAGENFÜHR, A. AND GOTTLÖBER, C. (2007-B) Verstärkungsmöglichkeiten an kleinen Vollholzholzquerschnitten mittels faserverstärkter Kunststoffe. Teil 3: Unterschiedliche Herstellungsverfahren im Fokus. *holztechnologie*, 48(5), 36-39.

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In-situ tensile loading and synchrotron micro-tomography of glued Norway spruce samples

M. Zauner[1*], F. Ritschel[2], M. Stampanoni[3], P. Niemz[2]

[1]Wood Physics, Institute for Building Materials, ETH Zurich, Stefano-Franscini-Platz 3, 8093 Zurich, Switzerland, mzauner@ethz.ch

[2]Wood Physics, Institute for Building Materials, ETH Zurich, Stefano-Franscini-Platz 3, 8093 Zurich, Switzerland, mzauner@ethz.ch

[3]Institute for Biomedical Engineering, ETH Zurich, Gloriastrasse 35, 8092 Zurich, Switzerland

Keywords: Synchrotron micro-tomography, Norway spruce, in-situ loading, tension, bonded wood

ABSTRACT

Recently the use of wood products and bonded wood is gaining increasing interest. The properties, especially the failure behaviour of wood and adhesive on the microscopic scale, are not completely understood yet and still the focus of on-going research. The reaction of bonded wood to load depends on a variety of factors, e.g. the structure of the wood and penetration depth (e.g. (Gavrilovic-Grmusa et al. 2012)). Glued structures further complicate the behaviour in comparison to wood and the possible failure patterns. Due to the speed and the opaque nature of wood, the observation of the origination and development of these processes inside the sample necessitate sophisticated non-destructive methods such as in-situ synchrotron micro-tomography. Although this method has been available and has been used for clear wood specimen ((Forsberg et al. 2008; Derome et al. 2011; Zauner et al. 2012)), it has not been applied for the observation of bonded wood loaded under tension.

To observe and possibly quantify the failure behaviour, such as developing cracks in wood and glue, a specifically designed in-situ loading device (Zauner et al. 2012) was used in combination with synchrotron micro-tomography at the Tomcat-beamline (PSI, SLS Villigen). This allows the observation of the glue-line and the complete wooden structure inside the undamaged sample starting with the original state up until failure and afterwards a comparison of the states. The sample shape and set-up were designed to allow an additional in-situ monitoring with acoustic emission (see (Ritschel et al. 2013)).

An example for failure mechanisms is shown in Fig. 1. The clear wood was bonded with urea-formaldehyd (UF). Fig.1a) depicts the initial, unloaded state, while (b) represents the failed sample. Failure is mainly found and initiated in the lower-density earlywood and connected to the sample surface. Fiber bridging of fibers and fiber bundles can be found in the sample. The results clearly show cracks, as well as different failure mechanisms developing in wood.

Wood loaded in different directions shows a deviating behaviour.

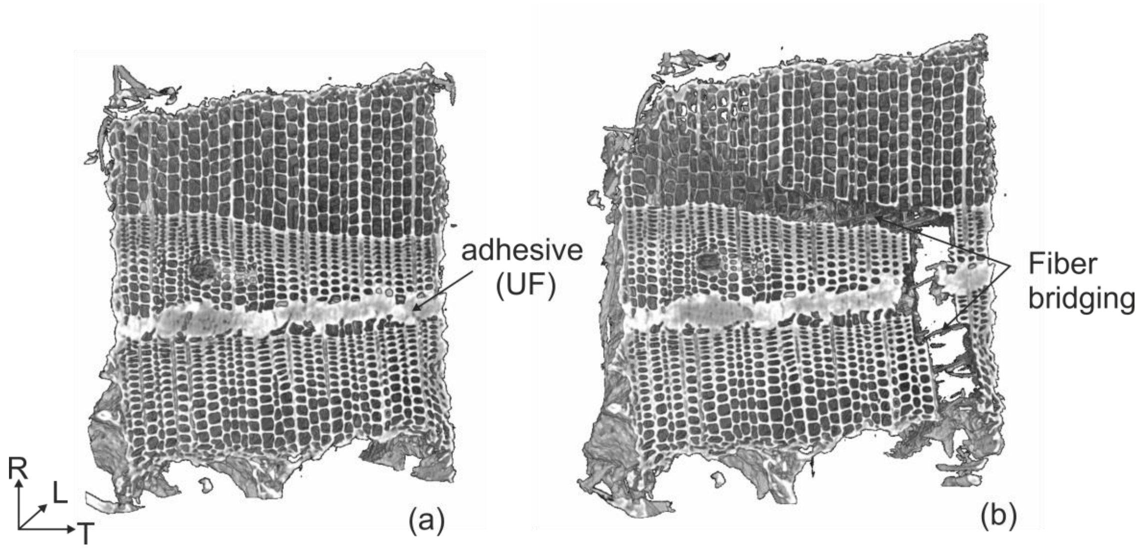


***Figure 3:** Deformation of tensile loading of a radially bonded specimen in the longitudinal direction. (a) depicts the original state and (b) the failed sample.*

In the future, the test method may be used to quantify the changes and failure mechanisms of the structure developing under increasing load, especially with a combination of 3D-tomographies and acoustic emissions.

REFERENCES

Derome, D., Griffa, M., Koebel, M., Carmeliet, J. (2011) Hysteretic swelling of wood at cellular scale probed by phase-contrast X-ray tomography. Journal of Structural Biology. 173:180-190.

Forsberg, F., Mooser, R., Arnold, M., Hack, E., Wyss, P. (2008) 3D micro-scale deformations of wood in bending: Synchrotron radiation mu CT data analyzed with digital volume correlation. Journal of Structural Biology. 164:255-262.

Gavrilovic-Grmusa, I., Dunky, M., Miljkovic, J., Djiporovic-Momcilovic, M. (2012) Influence of the degree of condensation of urea-formaldehyde adhesives on the tangential penetration into beech and fir and on the shear strength of the adhesive joints. Eur. J. Wood Wood Prod. 70:655-665.

Ritschel, F., Zauner, M., Sanabria, S., Brunner, A., Niemz, P. (2013) In-situ Kombination von Schallemissionsanalyse und Röntgen-Mikrotomografie mit Zugversuchen an Miniatur-Prüfkörpern aus Fichtenholz. DGZfP - Jahrestagung 2013 Dresden. Vol. BB 141 CD

Zauner, M., Keunecke, D., Mokso, R., Stampanoni, M., Niemz, P. (2012) Synchrotron-based tomographic microscopy (SbTM) of wood: development of a testing device and observation of plastic deformation of uniaxially compressed Norway spruce samples. Holzforschung. 66:973-979.

POSTER FLASH PRESENTATIONS II

Adhesives formulated with natural sustainable components for wood boards.

A. Ballerini [1], M. Núñez [2], N. Reyes [3].

[1] Wood Engineering Department, Universidad del Bío-Bío. Avenida Collao 1202, Concepción. CHILE.

[2] Compound Materials and Adhesives Laboratory, Universidad del Bío-Bío. Avenida Collao 1202, Concepción. CHILE.

[3] Chemical Sciences Faculty, Universidad de Concepción, Edmundo Larenas 294, Concepción, Chile.

aballeri@ubiobio.cl

Keywords: wood adhesives, compounds based on lupine flour, wood boards**.**

ABSTRACT

The use of adhesive systems containing formaldehyde in wood boards manufacturing has been restricted in different markets due to the damages it causes to the health of the people and the environment. This scenario, along with the interest in using sustainable raw materials that are not made of fossil fuels, such as adhesives using formaldehyde as a base, has generated a strong interest among Scientists to research and develop new adhesive systems based on natural resources.

The present work had the purpose of developing and validating different adhesive systems based on Tripol, a natural component developed using lupine flour as a base, as wood adhesive. Various Tripol-base adhesives were produced with and without the incorporation of other additives to strengthen the interaction with wood, such as urea, sodium hydroxide and hexamine, in percentages of 5% in relation to Tripol. A commercial-type urea-formaldehyde (UF) adhesive was used as control.

In order to evaluate the relativity of the adhesive samples, a dynamic mechanical analysis (DMA) was run, monitoring the flexural elasticity modulus during a temperature scanning (Fig.1).

The best adhesive systems were validated by producing particle boards which physical-mechanical properties were evaluated (Table 1).

The perpendicular tensile strength of the Tripol-based boards manufactured differed between 0.32 and 0.46 N/mm^2, whereas those using UF it was 0.36 N/mm^2. The swelling of the Tripol-base boards differed between 49% and 60%, and it was 35 % for the boards with UF. The formaldehyde emission of the Tripol-based boards was 0.04 mg/100 mg, and the emission of the UF board was 6 mg/100 mg. The results validate the use of Tripol-based adhesive systems for the manufacture of boards using wood without formaldehyde.

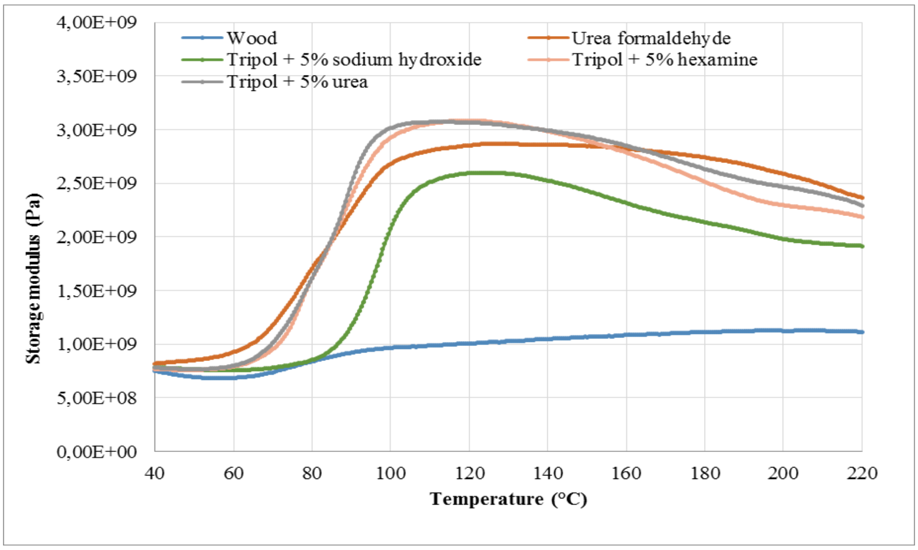


Figure 1: Dynamic Mechanical Analysis of adhesives samples.

Table 1: Particle board properties

Adhesive	**Internal bond[a] [N/mm^2]**	**Swelling[b] [%]**	**Formaldehyde emission[c] [mg/100 mg]**
Urea formaldehyde	0.36	35	6
Tripol + 5% urea	0.46	49	0.04
Tripol + 5% sodium hydroxide	0.32	60	0.05
Tripol + 5% hexamine	0.41	55	0.07

[a]EN319,[b]EN37, [c]EN120 (Standards).

REFERENCES

AMARAL-LABAT, G. A., PIZZI, A., GONÇALVES, A. R., CELZARD, A., RIGOLET, S., ROCHA, G. J. M. 2008. Environment Friendly Soy Flour-Based Resins without Formaldehyde. In: Journal of Applied Polymer Science, **18**, 624-632.

PIZZI, A. 2006. Recent developments in eco-efficient bio-based adhesives for wood bonding: opportunities and issues. Journal of Adhesion Science and Technology, **20**(8), 829-846.

CHENGA E., SUNA X., KARRB G. 2004. Adhesive properties of modified soybean flour in wheat straw particleboard. Composites: Part A 35, 297–302.

FRIHART, C. R., BIRKELAND M.J., ALLEN A.J., WESCOTT J.M. 2010. Soy Adhesives that Can Form Durable Bonds for Plywood, Laminated Wood Flooring, and Particleboard. Proceedings of the International Convention of Society of Wood Science and Technology and United Nations Economic Commission for Europe – Timber Committee October 11-14, 2010, Geneva, Switzerland.

Design of wood products using the method of welding wood

D. Domljan[1], I. Župčić[2], I. Grbac[3], M. Uremović[4]

[1-4]University of Zagreb Faculty of Forestry, Department of furniture and wood products, Svetosimunska 25 10000 Zagreb, Croatia, ddomljan@sumfak.hr; izupcic@sumfak.hr; ivica.grbac@zg.t-com.hr

Keywords: design, solid wood, welding methods, longitudinal connecting, constructions, innovations

ABSTRACT

Contemporary design is often at the brim of change and is more focused on presenting concepts and designing processes than new products. The scientific community in collaboration with designers has an important role in the development of new constructions implemented in innovative product concepts. One such approach is used at the Department of Furniture and Wood Products of the Zagreb Faculty of Forestry, where designers, constructors and students have initiated an interdisciplinary cooperation.

The paper represents a contribution to new findings in the field of applying innovative construction joints in designing furniture and other wood products. It includes sketches and designers ideas of potentially designing wood products by applying the longitudinal connecting of turned elements by the method of welding. Further research is necessary in this field in order to justify the application of this type of joints from the standpoint of the various aspects of design.

Welding solid wood

Reaching an ideal construction joint that would be applicable in design practice is by no means an easy and simple task both for designers and constructors. The research obtained in constructions using the method of rotational dowel welding into the surface and the longitudinal connecting of turned elements was done at the University of Zagreb - Faculty of Forestry (ŽUPČIĆ, 2010). Studies done on the subject of rotational welding of solid wood indicate a high level of firmness in the welded joint. This included the main factors that influence the process of welding such as the duration of the welding, welding tightness, welding depth, the effect of modification (thermal and chemical), wood type, the dowel rotation frequency, wood density (same wood type), tree ring width, dowel type, etc.

Next step of the investigations is interesting phase for the designers – how to make this researches functional and usable in some industrial wooden products?

The application of welded wood in the design of products

Investigation started with the interdisciplinary collaboration where designer, constructor and a student got a task to design a few products using the method of welding wood (Figure 1a).

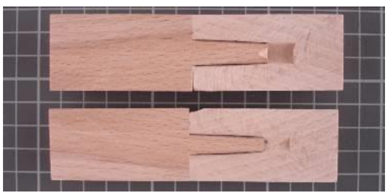
a)  *b)* 

Figure 1: a) Cross section of a longitudinally connected turned element by welding with a dowel of 30 mm in length (Župčić, 2010) b) massive wood beads and irregularly turned massive elements

In this phase some existing design which use similar form or material are found (so called *index of design*). (Figure 1b).
Next step was to sketch some new ideas using welded wood as the main constructive part of the product. Figure 2 show some of designers' ideas using designer drawing method (sketching). During this design phase some of results from the thesis (ŽUPČIĆ, 2010) were took into consideration. E.g. the effect of tightness which influences the firmness of the welded dowel in the surface, welding thermally and chemically modified wood or even the duration of the welding process.

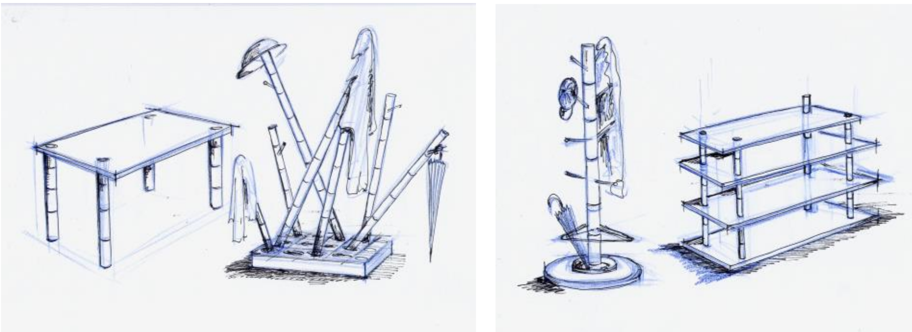


Figure 2: Design ideas - sketches of products using welded wood, by Domljan, D.

In the final phase prototype was make, using existing welded wood sticks and cardboard plates (Figure 3). It was shown for the first time at the international fair Ambienta in Zagreb in 2012.

Figure 3: The shelving unit produced from longitudinally connected turned elements by the method of welding, international fair Ambienta 2012, Zagreb

Conclusion
This study set out to design wood products by applying the technique of welding solid wood. Further research is necessary in this field so as to justify the application of this type of joints from the standpoint of the various aspects of design – novelty, innovation, economy, ecology, ergonomic, technology, etc, as well as confirmation of the feasibility, durability and strength of these constructive joints from the designers' standpoint.

REFERENCES

ŽUPČIĆ, I. (2010) Factors of that effect connection of beech turning elements by wood welding process (in Croatian), doctoral thesis, University of Zagreb Faculty of Forestry, Zagreb.

Effect of heat treatments on selected properties of Tree-of-Heaven (*Ailanthus altissima*)

T. Gyuricsek[1], N. Horváth[2], R. Németh[3]

[1,2,3] University of West Hungary

Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts
robert.nemeth@skk.nyme.hu

Keywords: Tree-of-Heaven, Ailanthus altissima, heat treatment, Anti-swelling efficiency

ABSTRACT

In the frame of wood modification research program at the Institute of Wood Science in Sopron were investigated wide range of hardwoods as well. This short report as a poster presentation would like to present our scientific activities in the field of dry heat treatments of Tree-of-Heaven (*Ailanthus altissima*). Ailanthus in China, its country of origin, counts as the second most important timber species (BRANDNER AND SCHICKHOFER 2013) and has nowadays importance in Europe's forests as well. In comparison to the appearance, physical and mechanical properties of the European ash (*Fraxinus excelsior*) a strong affinity was verified (MOLNÁR AND BARISKA 2006, BRANDNER AND SCHICKHOFER 2013).

The experimental thermal treatments were carried out under atmospheric conditions without added steam or injected water. These "dry heat treatments" were performed with schedules at 180° C and 200 ° C temperatures and 10 hours duration. After the treatments the density, the swelling and the equilibrium moisture content were determined. The colour changes were also measured according to the CIE Lab measuring system.

The investigation was focused on the change of wood properties caused by the dry heat treatment. The native specimens were sawn out in radial direction from one tree with wide annual rings. In this way six series of samples were produced from six annual rings (selected were the No 3, 5, 7, 9,11 and 13th). So the radial dimension of the samples was 7mm, which was cut out parallel to the tangent of early-late wood boundary. The tangential and the longitudinal measurements of the samples were 20 and 30 mm respectively.

The native and the treated samples were acclimatized under laboratory conditions. Relative air humidity was 65% and temperature was 20°C (normal climate). Equilibrium moisture content was determined from the oven dry weight and the weight at the normal climate, which is measured after reaching the constant weight. It was established, that the average moisture content of native series of Ailanthus was 13,6 %, and the first group's one treated at 180°C was 7,2 %. After the schedule at 200°C showed the samples averagely 4,8 % moisture content at normal climate. The differences of the moisture content in case of the selected annual rings were not significant in comparison to each other.

The determination of density was carried out also at normal climate. The average density of the native wood was 641 kg/m^3. After the schedules at 180°C and at 200 °C were the average densities of the treated Tree-of-Heaven samples 604 kg/m^3 and 591 kg/m^3. The density of the native wood cut out from the 3rd annual ring was under 600 kg/m^3. In comparison to the other annual rings can be determined ca. 30-70 kg/m^3 differences as increase. It can be also mentioned, that the density seems to be only increased from inside up to the 9th annual ring of the untreated wood.

Terminology of the dimensional stability is in connection with the dimension change caused by the change of moisture content of the wood. Improvement of anti-swelling efficiency (ASE) is a result of decreased swelling and shrinkage as an effect of treatment.

It was established, that the dry heat treatment has the same effect on all the native wood series (independently on the annual rings). All the native samples showed the highest swelling. In case of the radial swelling of all series was determined significant decrease in the direction to sapwood. The tangential anti-swelling efficiency achieved ca. 19-26% in cease of the schedule at 180°C, and 32-44% in cease of the schedule at 200°C (Fig. 1).

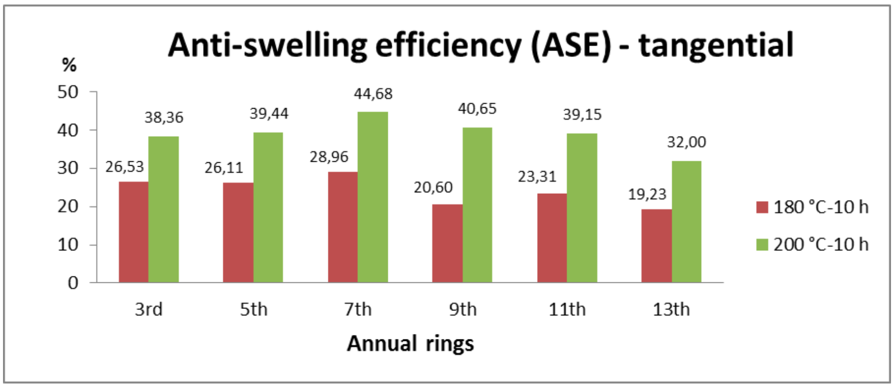


Figure 1: The improvement of ASE in tangential direction of wood

According to the results of colour measuring (CIE Lab) it was verified, that a dry heat treatment has a same effect on the Ailanthus wood samples. The lightness (L*) of the native specimens was 80,13, which decreased after the schedules at 180 °C and 200 °C to 59,15 and to 38,60. The average value of red colour component (a*) of native specimens was 3,67. As an effect of the thermal treatment the values increased by both schedules (at 180 °C was 9,99, at 200 °C was 11,75) and the materials turned to a reddish colour. The average value of yellow colour component (b*) increases from 23,25 (native) to 28,27 (at 180°C) and to 29,71 (at 200°C).

ACKNOWLEDGEMENTS

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REFERENCES

BRANDNER, R. AND SCHICKHOFER, G. (2013) The mechanical potential of the Tree-oh-Heaven, Holztechnologie, 54(2013), 5-12

MOLNÁR, S., AND BARISKA, M. (2006*)* Magyarország ipari fái / Wood species of Hungary, Published by Szaktudás Kiadó Ház Zrt. Budapest, pp. 62-65, ISBN 963 9553 96 4

Colour change and shape stability of open-air exposed solid wood panels made from heat-treated lime wood strips

C.M. Olărescu[1], M. Câmpean[2], A. Olărescu[3]

[1] Faculty of Wood Engineering – Department of Wood Processing and Wood Products Design – Transilvania University of Brasov, Str. Universitatii 1, 500068 Brasov, Romania, cristina.olarescu@yahoo.com

[2] Faculty of Wood Engineering – Department of Wood Processing and Wood Products Design – Transilvania University of Brasov, Str. Universitatii 1, 500068 Brasov, Romania, campean@unitbv.ro

[3] Faculty of Wood Engineering – Department of Wood Processing and Wood Products Design – Transilvania University of Brasov, Str. Universitatii 1, 500068 Brasov, Romania, a.olarescu@unitbv.ro

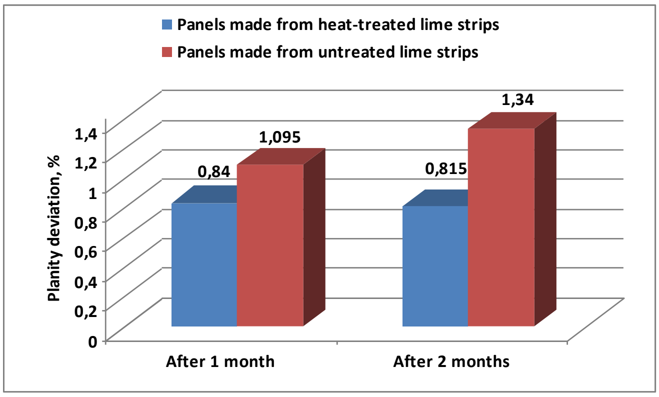
Keywords: heat-treated lime wood, solid wood panels, planity, colour

ABSTRACT

The paper presents the results of an experimental research concerning the shape and colour stability of solid wood panels made from heat-treated lime wood strips, compared to identical panels made from untreated wood. Lime wood strips of 300x50x20mm were heat-treated in an electric oven in the presence of air, at atmospheric pressure. The heat treatment comprised in the first stage oven-drying at 103ºC, followed by a heating stage at 150ºC for 8 hours, then actual heat-treatment at 200ºC for 3 hours and finally 12 hours of cooling. The heat treatment parameters were established based on the results of a preliminary research, so as to obtain a mass loss of 5%. Both the heat-treated and untreated lime wood strips were further used to manufacture ten 300x300x20mm panels of each type. The panels were open-air exposed for two months (February and March) on an uncovered terrace. The planity and colour of the panels were measured initially, after 1 month and after 2 months of outdoor exposure, in order to evaluate the shape stability (planity deviation) and colour modification (ΔE) of the panels made from heat-treated wood compared to those made from untreated wood under outdoor conditions, in time.

Shape Stability

The planity of each panel was measured in five points by means of an OPTOdesQ Measurement Table. The shape stability was evaluated by means of the planity deviation (in mm), calculated as the difference between the maximum and minimum absolute value of the five measured ones. As shown in Fig. 1a, the panels made from heat-treated wood strips preserved better shape stability, their planity deviation being by 3% smaller after one month and by 22% smaller after two months of open-air exposure than for the panels made from untreated wood. The maximum planity deviation was always obtained in the central point of the panel. The planity deviation in longitudinal direction after two months was negligible, ranging between 0.02 and 0.10 mm for the heat-treated panels and between 0.05 and 0.33 mm for the untreated ones. However, in transversal direction the values were much higher for the untreated panels: 0.33-0.85 mm, compared to 0.08-0.30 for the treated ones, as can be seen in Fig. 1b, c.



a.

b.

c.

Figure 1: Planity deviation (a) of solid wood panels made from heat-treated (b) and untreated (c) lime wood strips

Colour modification

The *L*a*b* colour coordinates were measured in nine marked points on each panel by means of an Avantes AVA SPEC 2048 spectrophotometer. Fig. 2 presents the colour modification of the panels made from heat-treated and untreated wood after one and two months of outdoor exposure, respectively. It can be noticed that the heat-treated panels suffered an evident colour modification even after one month of exposure to UV light. Their colour turned from gold-brownish (in initial state) into silver-grey after two months of open-air exposure. The panels made from untreated wood suffered more severe colour change after each month. The difference in lightness between the heat-treated and untreated panels was attenuated in time, being reduced from 39 (in initial state) to 18 after 2 months. However, even if their colour was very much affected by the open-air exposure, the specific gloss of the heat-treated panels was maintained.

L*=41, a*=9, b*=16
a. Heat-treated panel, initial

L*=46, a*=8, b*=15, ΔE*=5.02
b. Heat-treated panel,after 1month

L*=48, a*=5, b*=12, ΔE*=4.5
c.Heat-treated panel,after 2months

L*=80, a*=6, b*=21
d. Untreated panel, initial

L*=72, a*=9, b*=23, ΔE*=9
e. Untreated panel, after 1month

L*=66, a*=5, b*=17, ΔE*=10
f. Untreated panel, after 2months

Figure 2: Colour modification of solid wood panels made from heat-treated lime wood strips after 1 month (b, e) and after 2 months (c, f) of open-air exposure compared to initial state (a, d)

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Investigating the bending properties of hardwood reinforced poplar LVL

E. Vilpponen[1], Sz. Komán[2], L. Bejó[3]

[1]Aalto University – School of Science and Technology – Otakaari 102150 Espoo, Finland

edit.vilpponen@aalto.fi

[2]Instititute of Wood Science Hungary – University of West Hungary – H-9400 Sopron, Bajcsy-Zs. U. 4. Hungary,

szabolcs.koman@skk.nyme.hu

[3] Institute of Wood Based Products and Technologies – University of West Hungary – H-9400 Sopron, Bajcsy-Zs. U. 4. Hungary,

laszlo.bejo@skk.nyme.hu

Keywords: LVL, poplar, modulus of elasticity, bending strength, deterministic modelling

ABSTRACT

LVL is a high quality of wood-based structural material, with uniform mechanical properties and exact dimensions. Its use is favoured to sawn timber material, especially in long spam constructions. Suitable timbers with large diameter are more and more scarce nowadays. LVL is a product that can substitute natural sawn wood material in structural applications. In addition, using materials that come from a short distance from the building site is more environmentally friendly.

Poplar, through its short cutting rotation, provides a large quantity of raw material suitable for veneer production, even in a short time period. For this reason, it is often used as raw material in wood based construction elements. The elastic properties of LVL made of poplar can be enhanced by using veneer layers made of hardwood.

In this study, the mechanical properties of poplar LVL were improved using beech, turkey oak and tree-of-heaven as reinforcement layers. These raw materials are all available in the same region, so the transportation of the raw material can be minimized. The bending MOE and MOR of the experimental LVL were determined using vibration testing and destructive ramp testing. LVL's MOE was also estimated using a deterministic model based on the non-destructively determined MOE and the densification of the veneer layers.

The reinforcement layers improved the MOE significantly. Beech reinforcement performed as anticipated, while turkey oak and tree-of-heaven veneers increased the MOE more drastically than expected. This indicates that these veneers are especially suitable for this purpose. The theoretical model predicted the MOE of the control and beech-reinforced specimen reasonably well, but provided a conservative estimate for the effect of turkey oak and tree-of-heaven (Fig. 1). The prediction model used in this study can provide approximate MOE values for hardwood-reinforced poplar LVL. Further examinations are required to determine the reason for the better-than-expected improvement caused by certain hardwood veneer layers.

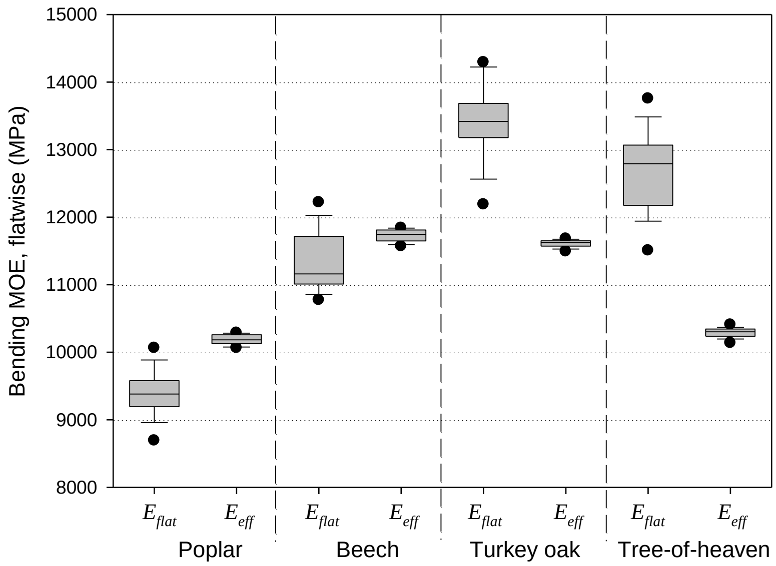


Figure 1: Comparison of the measured (E_{flat}) and modelled (E_{eff}) dynamic elastic modulus of poplar LVL, and the same modified with hardwood layers, with horizontal layer orientation (flatwise)

In contrast to the impressive improvement in MOE, the effect on MOR is much more modest (Fig. 2). In fact, MOR decreased when using beech reinforcing layers, and turkey oak and tree-of-heaven only provided very moderate increase. A one-way ANOVA test showed the effect of the reinforcing layers to be still significant on the MOR, but the only statistically significant difference was found between beech and tree-of-heaven reinforcement, based on Tukey's test. A possible explanation of the poor performance of hardwood reinforcement in terms of bending strength is inadequate bonding of the hardwood layers, with the glueline failing at higher stress levels.

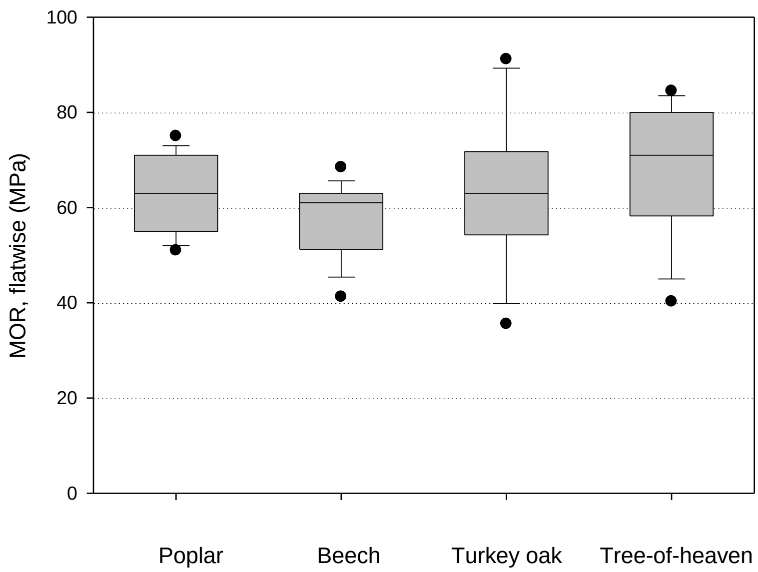


Figure 2: Comparison of the measured bending strength of pure poplar LVL, and that made using modified layers.

This study was supported by the Environment conscious energy efficient building TAMOP-4.2.2.A-11/1/KONV-2012-0068 project sponsored by the EU and European Social Foundation.

A preliminary study on dielectric properties of Poplar and Wood-based Panel

Wang Pei[1], Huang Siwei[1], Zhang Rui[1], Zhou Dingguo[1]

[1]College of Material Science and Engineering, Nanjing Forestry University, Nanjing 210037
wangpei08241@163.com

Keywords: dielectric grain direction frequency moisture content

ABSTRACT

The properties of wood were effected by many factors, such as microwave frequency, wood temperature, moisture content, surface roughness as well as grain direction, that a lot of research has been performed. The dielectric properties of four Canadian eastern wood species were determined by Ahmed Koubaa et al.(2008)in a certain range of moisture content and temperature, finding the dielectric properties varied with moisture content and microwave frequency, overshadowing the influence of wood species and wood temperature. To realize the efficient utilization of wood, Hamiyet Şahin Kol(2009),Cao Jinzhen, Zhao Guangjie(2001), W.S.Holmes et al(2013) and other researchers also did a lot of work respectively.

In this paper, we investigated the dielectric properties of Poplar at different moisture content in three structural directions and discussed the effects of the parameters, such as, moisture content, grain direction, and the frequency on dielectric properties. By analyzing the variation of the dielectric parameters, it has important theoretical basis to understand electrical properties and the process of heating, drying and gluing of wood. As for the studying of the dielectric properties of wood-based panel, it proposed a new use, such as heating from the floor.

The dielectric properties were determined by Dielectric Assessment Kit(DAK)which is made of Schmid & Partner Engineering AG, Switzerland. DAK contains three parts—PC, Vector Network Analyzer (VNA) and Probe. The thickness specimens (≧5mm) were needed.

Dielectric properties of Poplar wood

As we can see from Fig.1, the results indicate that the dielectric properties increased with rising moisture content within the range studied at a room temperature about 20℃.Dielectric constant increased with rising frequency, however dielectric loss tangent was the opposite. The direction parallel to grain had higher dielectric behavior than the transverse direction. Two facts are considered about the phenomenon, firstly, as the moisture content increases from the oven-dry condition, the polar components of the cell wall and cellulose get more freedom of rotation, leading to higher dielectric behavior. Secondly, the more water with high value of dielectric content, the higher dielectric behavior of the wood.

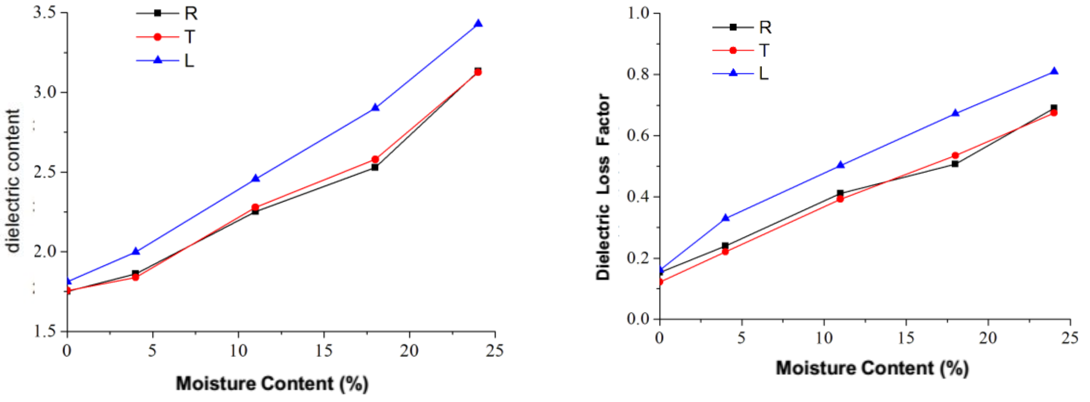
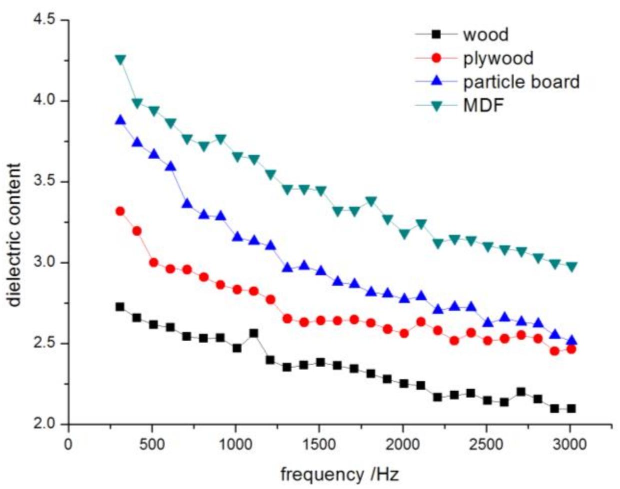


Fig.1 The relationship between dielectric properties with moisture content at a frequency of 1.01GHz.

Dielectric property of the wood-based panel



The results indicate that the four compositions had different dielectric behavior (Fig.2). The anisotropic of the composition became weaker along with the smaller diameter of the units of the panel, which improving the freedom of polar group. Then the polar groups in the compositions were changeful under the alternating electric field, and the value of dielectric content would increase.

Fig.2 The relationship between dielectric content and frequency.

REFERENCES

Ahmed Koubaa, Patrick Perré, Ron M. Hutcheon and Julie Lessard (2008) Complex Dielectric Properties of the Sapwood of Aspen, White Birch, Yellow Birch, and Sugar Maple. *Drying Technology*, 26, 568-578.

Hamiyet Şahin Kol (2009) Thermal and dielectric properties of pine wood in the transverse direction [J].*bioresources*,4(4),1663-1669.

Cao Jinzhen, Zhao Guangjie. (2001)Dielectric Relaxation of Adsorbed Water in Wood Cell Wall under Equilibrium and Non-Equilibrium State [J].*Forestry Studies in China*, 3(1), 71-77.

W.S. Holmes, S.C. Mukhopadhyay, and S.G. Riley(2013)Dielectric Properties of Wood for Improved Internal Imaging[J].Advancement in Sensing Technology, SSMI 1, pp. 93-104.

Analysis of extractives of tropical hardwoods and benefits for the surface treatment

R. Wanschura, E. Windeisen, K. Richter

HOLZFORSCHUNG MÜNCHEN, TECHNISCHE UNIVERSITÄT MÜNCHEN,
WINZERERSTR. 45, D-80797 MÜNCHEN, GERMANY
windeisen@hfm.tum.de

Keywords: Extractives, FTIR-ATR, GC/MS

The use of many tropical wood species is appreciated due to the often attractive wood colour and the high durability against wood degrading organisms. The beneficial combination of natural resistance and aesthetical appearance substantiate the use of tropical hardwoods in weather exposed applications as terrace flooring of claddings of buildings. To understand the variations of wood species in durability against fungi, discolouring of surfaces and dimensional stability under changing moisture conditions, the chemistry of the extractives needs to be known. The extractives of selected wood species (Table 1) consist of a great variety of components, of which not all are known (e.g. KILILC AND NIEMZ 2010, SANTA AND OKINO 2007, SCHWAGER AND LANGE 1998, TAKANORI 2008).
In Fig. 1 and 2, the variety of the extract contents in organic solvents (successively in petroleum ether, acetone and methanol) and in water with the corresponding pH-values are presented. The greatest differences are detected in the acetone extracts (Fig. 1). GC/MS analysis of the extracts allowed to identify a high variety of fatty acids as well as different steroids like sitosterol and stigmasterol, quinones like tectoquinone or lapachol and flavonoides like taxifolin. However, there are still difficulties in analyzing high molecular compounds, e.g. the ones which are present as glycosides.
Examination of wood surfaces by means of FTIR/ATR (Fig. 3, left) disclosed differences between the wood species and also changes due to extractions, e.g. with water (which simulates leaching in weather-exposure in a first attempt).
After analysing all data, it was possible to cluster several wood species into groups with similar substance classes (Fig. 3, right). This might allow to identify mechanisms responsible for the biological resistance and to develop surface treatments for a better preservation of wood.

Table 1: Examined tropical hardwood species

Trade name (used here)	**Scientific name**	Other trade names (selection)
Merbau	***Intsia spp.***	Malacca teak, Moluccan Ironwood, Ipil, Kwila
Jatoba	***Hymenaea courbaril***	Courbaril, Aalgarrobo
Muiracatiara	***Astronium graveolens***	Gonçalo alves, Zebrawood
Piquia	***Caryocar villosum***	Pequia, Grao Cavalo
Itaúba	***Mezilaurus spp.***	I. preta, I. vermelha, I. amarela
Ipé Noir, Ipé Rouge	***Tabebuia spp.***	Pau d'arco Arahonie, Lapacho
Cumarú Amarelo, Vermelho	***Dipteryx odorata***	Cumarú verdadeiro, Muimapagé, Koemaroe, Tonka
Massaranduba	***Manilkara bidentata***	Balata rouge, Bullet wood
Bangkirai	***Shorea laevis***	Balau, Selangan batu No.1
Teak	***Tectona grandis***	India-, Burma-, Java-Teak

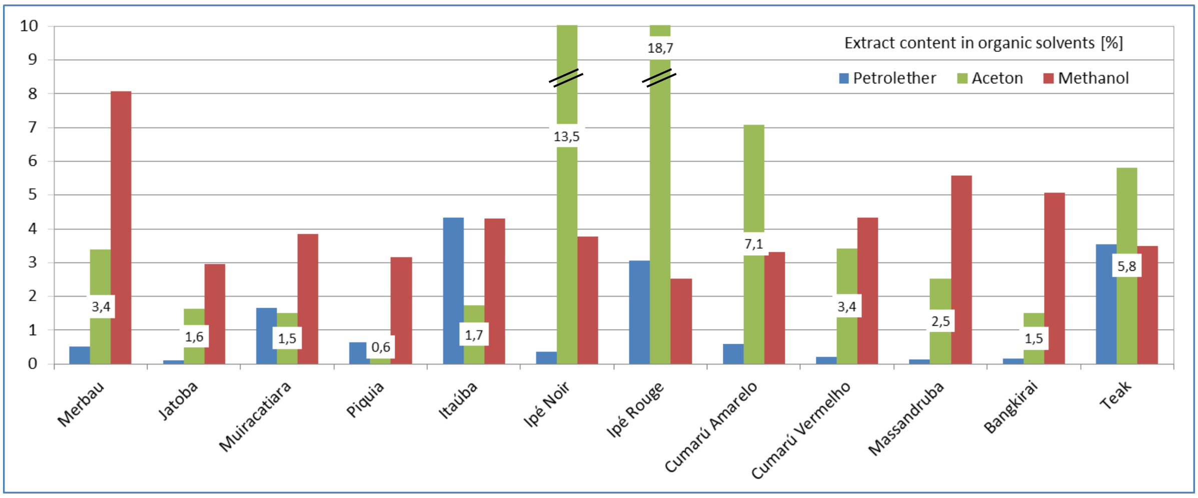


Figure 1: Extract content in organic solvents (PE: petroleum ether, Ace: acetone, and MeOH: methanol)

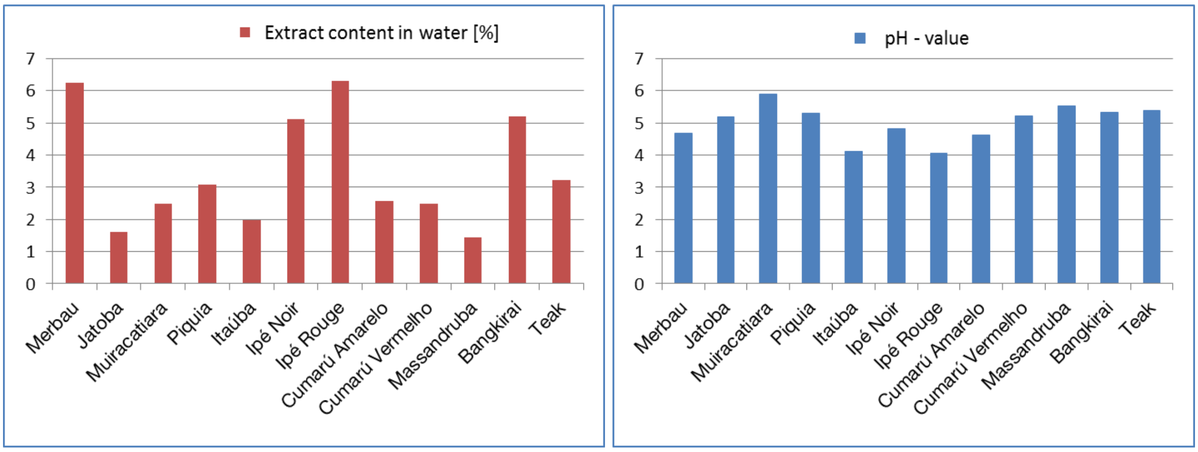
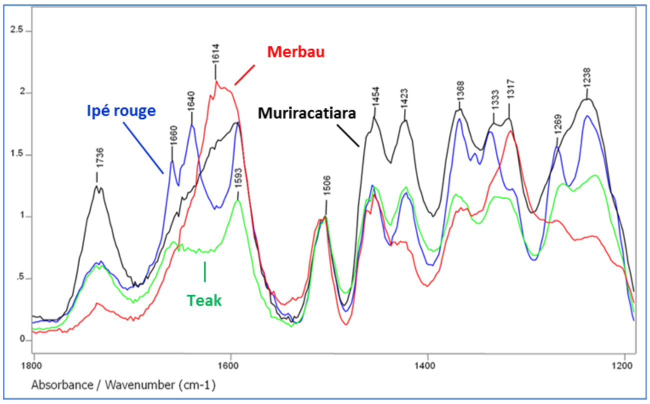


Figure 2: Extract content in water at room temperature (left) and the pH-values (right)



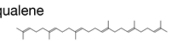
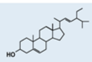
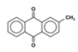
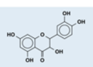
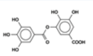
Substance class	Wood species	Example (representative)
terpenes	*Dipteryx odorata (amarelo, vermelho), Manilkara bidentata, Tectona grandis*	squalene 
sterols	*Dipteryx odorata (amarelo, vermelho), Hymenaea courbaril, Manilkara bidentata*	stigmasterol 
quinones	*Dipteryx odorata (amarelo, vermelho), Intsia spp., Astronium graveolens, Tabebuia spp., Tectona grandis*	tectoquinone 
flavonoids	*Hymenaea courbaril, Intsia spp., Astronium graveolens*	taxifolin 
tannins	*Dipteryx odorata (amarelo, vermelho), Astronium graveolens*	gallic acid derivatives 

Figure 3: FTIR-ATR spectra of four tropical hardwoods (left); substance classes of wood species (right)

REFERENCES

KILILC, A., NIEMZ, P. (2010) Extractives in some tropical woods. *Eur. J. Wood Prod.*, **68**, 79-83.

SANTA, M., OKINO, E. (2007) Chemical composition of 36 Brazilian Amazon forest wood species. *Holzforschung*, **61**, 469–477.

SCHWAGER, C., LANGE, W. (1998) Biologischer Holzschutz. Literaturstudie über akzessorische Bestandteile dauerhafter Holzarten mit resistenzwirksamer Aktivität. *Landwirtschaftsverlag GmbH*, Münster.

TAKANORI, I. (2008) Heartwood extractives from the Amazonian trees *Dipterix odorata*, *Hymenaea courbaril* and *Astronium lecointei* and their antioxidant activities. *J. Wood Sci.*, **54**, 470–475.

Effect of Compressive and Impregnating Resin Treatment on the Properties of Poplar Wood

Yang Zhang, Dingguo Zhou

College of Materials Science and Engineering, Nanjing Forestry University, 210037 Nanjing, P. R. China
yangzhang31@126.com, dgzhou@njfu.com.cn

Keywords: compressive treatment, impregnating resin treatment, property, Poplar

ABSTRACT

The compressed wood can be used as the structure solid wood product because compression treatment will enhance physical and mechanical properties of wood materials, such as modulus of elasticity, shear strength, surface hardness, etc. Poplar is one of the dominant forest plantation species in China. However, it cannot be used as product directly because its density is small, the structure is loose and the strength is low. It is sure that its value can be increased greatly if it can be made into compressed wood. In our research the objective was to investigate the properties of poplar wood compressed and impregnated with MF resin treatment. The method of vacuum treatment was used to impregnate MF resin into poplar, and then it was compressed, so as to increase properties of poplar. The results shows that if vacuum degree is 0.05MPa and the impregnated time is from 1h to 5h, both of the rate for increased weight and the dimensional stability of poplar impregnated with MF resin were increased clearly, and both of MOR and MOE for the poplar veneer dipped melamine resin were also increased clearly if the compressibility rate raised from 0 to 50 percent. After 8 hours water absorption the thickness of poplar impregnated with MF resin treatment changed much littler than that with no resin under the same compressive rate.

Table 1: Results of testing thickness swelling for poplar of different compression rate

Specimen	C-0[%]	C-10[%]	C-20[%]	C-50[%]
a	3.07	5.29	22.67	72.01
b	1.37	3.647	5.58	4.61

Note: a is poplar with no resin; b is poplar with MF resin; **C-0:** the compression rate of poplar is 0; **C-10:** the compression rate of poplar is 10; **C-20:** *the compression rate of poplar is 20;* **C-50:** *the compression rate of poplar is 50;*

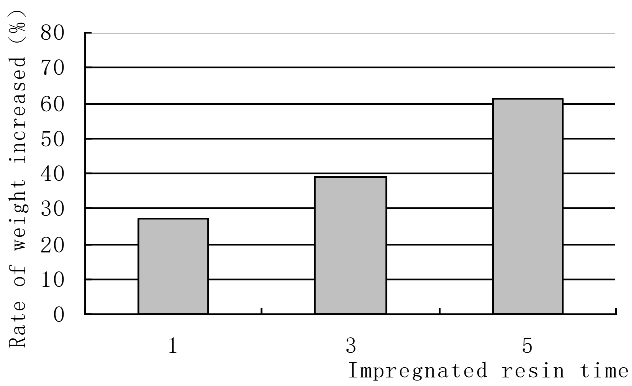


Figure 1: Relationship between the rate of weight increased and the impregnated time for poplar veneer

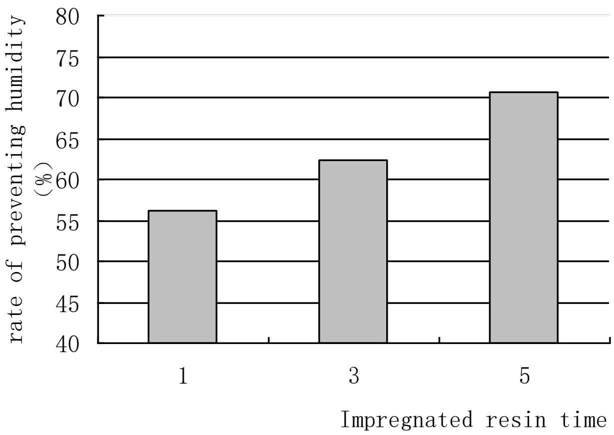


Figure 2: Relationship between the rate of preventing humidity and the impregnated time for poplar veneer

REFERENCES

CHEN, L. ZHOU, D.G. AND XIE, Y.Z.,(2006), Studies on the Changes of Forest Resources and the Strategy of Wood Industry Sustainable Development in Jiangsu Province, *Journal of Fujian Forestry Science and Technology* , 33(2),180-183.

HUA,Y.K. AND JIN,J.W.,(2006), Status and Development of the Southern Type Poplar Processing Industry in Jiangsu Province, *CHINA WOOD INDUSTR* , 20(2), 72-75.

KUTNAR, KAMKE FA, SERNEK M.(2009).Density profile and morphology of viscoelastic thermal compressed wood . *WOOD SCIENCE AND TECHNOLOGY*,3(1),7-68

Determination of coating stresses in a system wood–solid coating subjected to moisture changes

R. Lagaňa, J. Kúdela

Technical University in Zvolen, T. G. Masaryka 24, 96053 Zvolen, Slovakia,

lagana@tuzvo.sk, kudela@tuzvo.sk

Keywords: wood-coating system, stress, strain, DIC method, moisture load

ABSTRACT

This study proposes a method for determination of coating stresses on the surface of a wood-coating system subjected to moisture content changes. The method is based on the Hook's law. The strains were scanned with an optical two-camera system and evaluated with the aid of digital image analysis. The material investigated was a polyurethane (PUR) varnish applied on two beech wood. The wood was placed in an environment with a very high (almost 100 %) humidity, which caused its bending. The mapping of strains in the coated and uncoated surface allowed us to recognise the stress-strain development in the system wood-coating during wetting.

INTRODUCTION

Stresses in a solid coat applied on wood may develop during curing as well as in service conditions when the system is subjected to moisture, heat or mechanical loading. The moisture changes in the system wood-coating cause differences between the performance of wood and coating, and stresses originate in this system. These stresses are usually calculated from the deflection of coated samples (Perrera 1998, Kúdela and Rešetková 2012). Kúdela et al. (2010) used photoelastic method for mapping of stress distribution. Another optical method uses a two-camera system combined with Digital Image Correlation (DIC) technique and allows measuring of strain fields also for arbitrary surfaces (Duchêne et al. 2013).
The aim of this paper is to propose a non-destructive and contactless method for determination of stresses on coated wood surfaces subjected to moisture induced stresses.

MATERIALS AND METHODS

The experimental material was beech wood, radial specimens, 120 × 86 × 4 mm (R × L × T) in size. Their initial moisture content was 8 %. One surface of each specimen was treated with a polyurethane lacquer. The lacquer was applied on the radial surfaces of the test specimens, at an average thickness of 175 μm. Their lateral sides were sealed with a hydrophobic balsam, to guarantee one-way moisture uptake. Then the specimens were placed by two into a glass vessel, on two supports, 100 mm away. One of the specimens was placed with its coated face upside, the other downside. Thereafter, the vessel was closed and supplied with redistilled water. The uniform humidity distribution throughout the vessel (≈100 %) was attained with a fan.
The strain patterns on the surface were mapped with an two-cameras optical system Aramis 3D, facing the coated face of the first and the uncoated face of the second specimen. The specimens´ radial surfaces were sprayed with a marker to obtain a network of measuring points. These points served for determining basic lengths for measuring strains in the radial

direction. Simultaneously, the specimen´s deflection was measured in the specimen´s centre. The testing lasted for two weeks, with the measurements repeated at one-hour intervals.

RESULTS AND DISCUSSION

Due to the wetting, the average moisture content in the specimens increased from 8 to 31%. The asymmetric water uptake caused the specimens to bend. Firstly, the sample´s bending initiated compression stress originating on its PUR-coated surface. Despite of the increasing deflection, wood swelling started to alleviate this compression stress. After the deflection had reached its maximum, the coating became to be loaded in tension. At the same time, the increase of strain on the uncoated surface decelerated. The proportional limit of the PUR coating (22 MPa) was reached after 72 hours. Next, the calculated stress overestimated the actual values. Similarly as observed by Kúdela and Rešetková (2012), after levelling off moisture distribution across the thickness, the specimens were straightened and their deflection disappeared.

CONCLUSIONS

The proposed method enables to identify stresses developing on the coated surface of wood-coating systems subjected to moisture loading. The method is powerful in description of the complex stress-strain behaviour of these systems.

Acknowledgement: The research was supported by VEGA 1/0893/13.

REFERENCES

DUCHÊNE, L., BATTAIEB, A. B., TUNINETTI, V., HABRAKEN A. M. (2013) Numerical Modelling and Digital Image Correlation Strain Measurements of Coated Metal Sheets Submitted to Large Bending Deformation. Key Engineering Materials. (554-557), 2424-2431.

KÚDELA, J., PUŠKÁROVÁ, M., REŠETKA, M. (2010) Stress patterns in coating films during moisture loading of the system wood – solid coating. In.: Wood structure and properties 10. Zvolen: Technical University in Zvolen, 217–222.

KÚDELA, J., REŠETKOVÁ, M. (2012) Stresses in solid coatings on surface treated beech specimens, calculated from deflection values during wetting. Acta Facultatis Xylologiae. 54(2), 67–78.

PERERA, D. Y. (1998) Measurement of Stress in Multicoat Systems. The Journal of Coatings Technology. 70(881), 69–75.

Modelling the Hardwood Chain

A. Teischinger[1], M. Gronalt[2], S. Kühle[1]

[1)]Institute of Wood Science and Technology – Department of Material Science and Process Engineering – University of Natural Resources and Life Science, Konrad Lorenzstrasse 24, 3430 Tulln, Austria,
alfred.teischinger@boku.ac.at
skuehle@boku.ac.at

[2)]Institute of Production Economics and Logistics – Department of Economics and Social Sciences – University of Natural Resources and Life Science, Guttenberghaus, Feistmantelstr. 4, 1180 Vienna, Austria,
manfred.gronalt@boku.ac.at

Keywords: hardwood, supply chain, hardwood manufacturing, hardwood processing

ABSTRACT

In the last decades the softwood industry became a significant industrial sector in Europe operating in regional and overregional procurements but international sales markets. Reacting to a cost efficient production, especially in the primary processing (e.g. sawmilling, panel production) there was a huge shift from craft-like production to bigger production entities responding to the rule of economy of scale (Silvestre 1987). In hardwood production comparative smaller entities are still the rule, but the various productions units such as sawmills, components and cantles producer and producer of final products operate in a complex supply chain network. But the hardwood production sector faces new challenges.

The progressive orientation of a company towards more flexible, individualized and specialized product suppliers increases additionally the density of the flows (Kuhn 1995). The hardwood industry has to react to these international and environmentally-changing trends.

Due to many reasons the current hardwood process chains are not efficient enough and a huge part of the hardwood resources (especially in beech) are allocated to the pulping process or to the energy sector (Mantau 2012).

In the current project we want to understand the various process chains and their interaction by analysing and modelling the sector. Essential for the process chain analyses are the various techniques of supply chain management, which we want to apply in order to map the sector and eventually develop new ideas for establishing a competitive hardwood sector. In contrast to the different process chains of softwood with a strong commitment towards supporting and stiffening applications in the construction industry there is high diversity in the usage of hardwood products. Besides its main applications as the various solid wood applications, veneer- and laminated-based materials (veneer, plywood), other wood-based materials based on hardwood are being discussed. For the design of an efficient production network for hardwood appropriated inter-company planning methods need to be developed. These may help to improve the competitive position of individual actors as well as the entire network (Németh and Teischinger 2012).

The first step is therefor to draw a linear, process-oriented inventory analysis of the network actors. The cooperation along the material flow companies are central points of the process chain. From this, the first abstract model will be set up as shown in Figure 1. The vertical direction of the figure describes the scale of depth with classifications into levels. Either the user of the model considers the associated companies or the manufacturing process is significant. The horizontal direction describes a progress of a process chain and thus the

development over time. The resulting model should have the claim of precision and accuracy, so that it can be successively extended and completed.

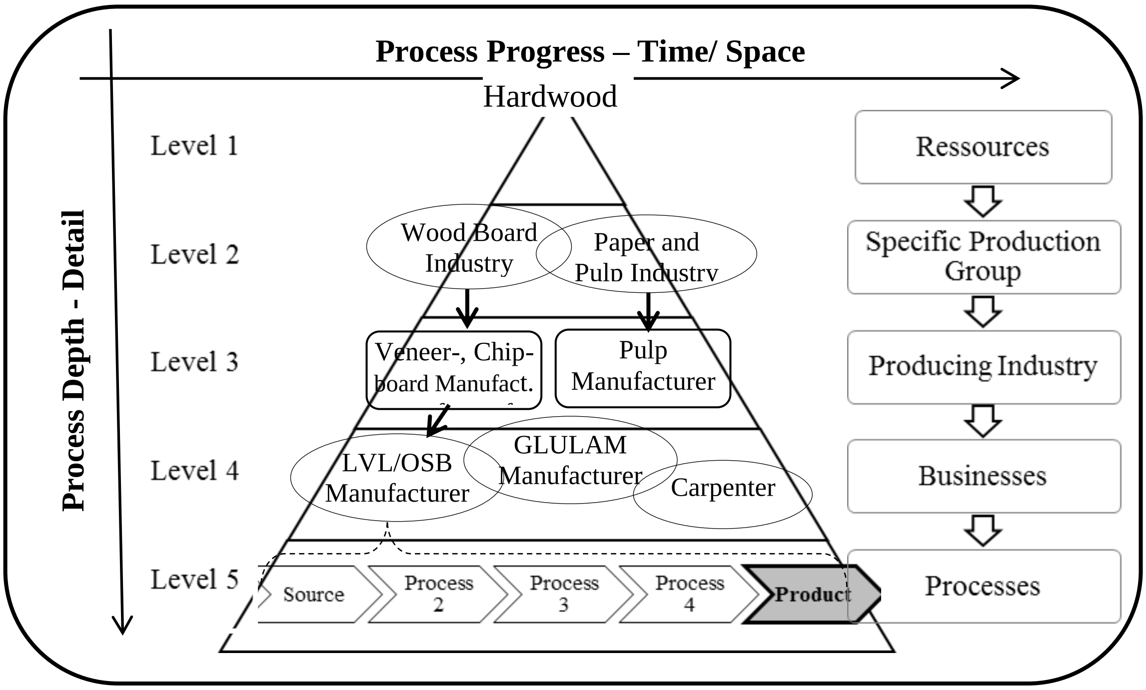


Figure 1: Example of an abstract model of the hardwood supply chain based on the system decompositon (based on Kühling 2000)

Future goals are the decomposition of the edit and manufacturing processes of the hardwood industry and the inquiry of their interaction. The reason behind this mode of procedure is to obtain uniform process elements and the inquiry of the information processing and formation while the synthetically accumulation of the individual process elements. Subsequently this information is incorporated into the model of hardwood supply chain. The abstract model enables the simulation of scenarios along the process chain to locate the potential key sections. The information-related cooperation achieves a growing competitiveness of the entire networks and better positioning of each actor.

REFERENCES

KUHN, AXEL (1995): *Prozeßketten in der Logistik. Entwicklungstrends und Umsetzungsstrategien.* Dortmund: Verl. Praxiswissen (Unternehmenslogistik).

KÜHLING (2000): *Gestaltung der Produktionsorganisation mit Modell- und Methodenbausteinen.* Deutschland, Universität Dortmund, 2000, S.71-74.

MANTAU, U. (2012): *Holzrohstoffbilanz Deutschland, Entwicklungen und Szenarien des Holzaufkommens und der Holzverwendung 1987 bis 2015*. Deutschland, Hamburg, 2012, 65 S.

NÉMETH, RÓBERT; TEISCHINGER, ALFRED (2012): *The 5th conference on hardwood research and utilisation in Europe 2012*. September 10-11, 2012. Sopron: University of West Hungary.

SILVESTRE, JOAQUIM (1987): *Economies and Diseconomies of Scale.* 1987.

SESSION IV
INDUSTRIAL APPLICATIONS

Improving quality and yield of rotary peeled beech veneers for plywood production

H. Buddenberg[1], P. A. Buddenberg[2], R. Meyer[1], K. Richter[1]

[1] Technische Universität München, Holzforschung München, Winzererstr. 45, 80797 München, Deutschland, e-mail: buddenberg@hfm.tum.de

[2] Buddenberg-Agentur, von Vinckestr. 36, 33014 Bad Driburg, Deutschland, e-mail: Philipp-Adolf.Buddenberg@gmx.de

Keywords: beech rotary veneer, yield, press drying, clipping

ABSTRACT

Germany has had a long tradition in beech plywood production. During the last 30 years a decline in this industry took place though. This was due to increasing labor costs and rising prices for roundwood of beech in Germany. In the course of opening markets in Eastern Europe upon German unification Eastern European beech plywood producers in the early nineties appeared as significant competitors to German plywood companies in terms of lower wages and prices. Therefore some German plywood producers, in their effort to keep competing, shifted their veneer production to Eastern European countries like Romania or Hungary. Beech plywood has superior strength properties (i.e. bending strength, modulus of elasticity) to softwood plywood and can well be defined as engineered wood product being suitable for various constructive applications. Two main reasons are generally associated with the current marginal status of beech plywood as commodity product for constructive purposes. One reason is related to the weak durability of beech wood which impedes its utilization for exterior applications. The other reason lies, at least for highly industrialized countries, in the poor cost effectiveness of the production process. This is due to the low degree of industrial automation and therefore the need for a relatively high share of human labor as well as a relatively low wood yield at the end of the production process. The latter reason leads back to the properties of beech as wood species determining thus the biological conditions during the production process. Due to its low durability against decay the knots in beech wood tend to turn black and become soft spots being periodically visible along the peeled veneer layer during production process. For surface veneers and for constructive applications these spots need to be clipped out from the veneer layer thereby wood yield is reduced. Due to its relatively high density beech wood has a high sorption capacity which leads to a high shrinking and swelling especially in tangential direction. Therefore rotary peeled veneers intensely deform after the drying process and thus tend to become waved and build cracks along the grain direction. Both appearances are undesirable for further processing.

In our current research project we define a technique which allows for gaining higher wood yields during rotary veneer production by reducing the amount of waste from veneer clippings. We further study press drying as an alternative processing method to improve the planeness and the tangential stability of beech veneer. During veneer production process the highest portion of veneer loss is caused through the cutting phase (clipping) in which defects i.e. knots and cracks are selected from the veneer layer. Experimental studies in a beech plywood plant have determined that portion being about 20% from the total veneer area being produced excluding the tangential veneer loss caused by drying [Buddenberg, Ph., 1992].

Since the clipping applies along the complete length of the continuous veneer layer the selected veneer stripes (clippings) do not only cover regions of defects but also good regions of veneer.

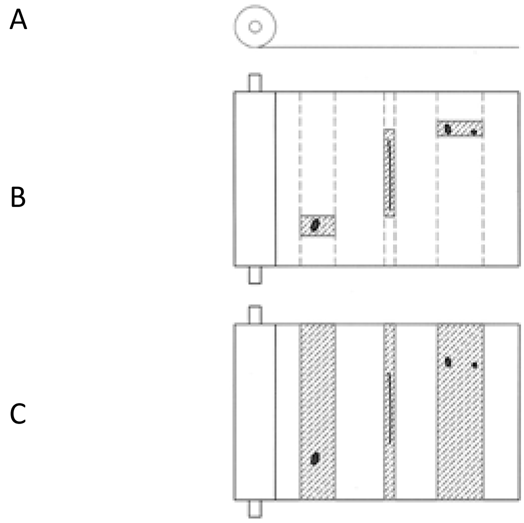


Figure 1: Veneer loss through clipping: A: Cross-section of log and peeled continuous veneer layer; B: Areas of defects within clippings; C: Total areas of clipped veneer stripes

Statistical investigations as well as empirical studies on the actual regions of wood defects within a continuous layer of beech veneer estimated that portion being for a medium wood quality (German B-grade) at maximum only 2-2.5% [Marutzky et. al., 2008]. By applying an image analysis software the current research project assesses on the basis of visual analysis of scanned veneer samples in how far good areas of veneer clippings could be selected from the clippings and further be processed instead of being treated as waste.
A further research focus is the testing of press drying of wet beech veneers on a laboratory press in comparison to oven drying of veneers. The press dried and oven dried veneers are compared according to their tangential shrinkage in different climate conditions and according to their planeness, dimensional flexibility and the amount of (press) drying cracks. First results show a significant reduction in tangential shrinkage and a higher planeness and dimensional flexibility of press dried veneers in comparison to oven dried veneers. Further research aims at assessing and comparing strength properties of laboratory plywood panels based on press dried and oven dried veneers.

REFERENCES

BUDDENBERG, Ph. A (2014) Personal records based on practical tests in 1992

MARUTZKY R., ADERHOLD, J., PLINKE, B. (2008) *Final Report of Research project: Hochwertige Verwendung von Starkholz durch Schälfurnierprodukte aus stark dimensionierten Nadel- und Laubhölzern-Teilprojekt 1:Evaluierung und Weiterentwicklung der Technologie zur Herstellung von Furniersperrholz- FKZ:0330552A- financed by German Federal Ministry of Research.*

The strengths and weaknesses of load bearing joints in beech wood applications

S. Denzler[1], M. Zscheile[2]

[1] University of Applied Sciences Rosenheim, Faculty of Wood Technology and Constructions, Department of Research and Development, Hochschulstr. 1, 83024 Rosenheim, Germany
sebastian.denzler@stud.fh-rosenheim.de

[2] University of Applied Sciences Rosenheim, Faculty of Wood Technology and Constructions, Department of Research and Development, Hochschulstr. 1, 83024 Rosenheim, Germany
matthias.zscheile@fh-rosenheim.de

Keywords: beech wood, CLT, load bearing joints, bonding

ABSTRACT

Beech wood will be an increasingly important timber resource, because the demand for beech wood is expected to grow in the coming decades (BAYSF 2011). Accordingly, current thinning and reforestation practices are in place to increase the availability of beech wood in German and European forests. However, the key to maximizing the potential of beech wood lies in joint bonding, where the strength and stability of the joints require strict control of adhesives and adherents, coupled with a closely monitored reaction and bonding time schedule. In addition to these factors, for load bearing applications the resistance of the products to moisture must also be regulated in order to ensure structural stability. These considerations, alongside the other material drawbacks of beech wood such as the high shrinkage and swelling, the alignment of annual rings and lamella thickness, all serve to complicate the process of bonding beech wood. In particular, the different adhesive types, their availability and formal approval for usage remain barriers to optimizing the bonding of beech wood (OHNESORGE ET AL. 2008, SCHMIDT ET AL. 2010).

Given the market value of beech wood products yet acknowledged difficulties in its processing, the goal of our research project is to identify to optimal adhesives and gluing process for joint bonding As part of the research project we produced and tested structures of cross-laminated timber (CLT) made from pure beech wood as well as hybrid constructions. The dimensions of the specimens were 10 x 10 mm (length by width), and beech lamellas had a thickness of 20 mm. The adhesive systems – three types of melamine urea formaldehyde (MUF), one polyurethane (PUR), one phenol resorcinol formaldehyde (PRF) and one emulsion polymer isocyanate (EPI) – were selected because they are they are commonly used at present. From each adhesive we produced 21 specimens, which were then tested for delamination in accordance with FprEN 16351. This coming norm states that: the total delamination length should not exceed 10% of the sum of all glue lines; the maximum delamination length should not exceed 40% of the total length of a single glue line; and the wood failure rate of the sum of all split glued areas should not be greater than 70%. After the test cycle we measured the degree of delamination and all samples were split, regardless of their delamination values, to provide comparable test results. The individual results were averaged as a basis of comparison for the performance of the different adhesives (Table 1).

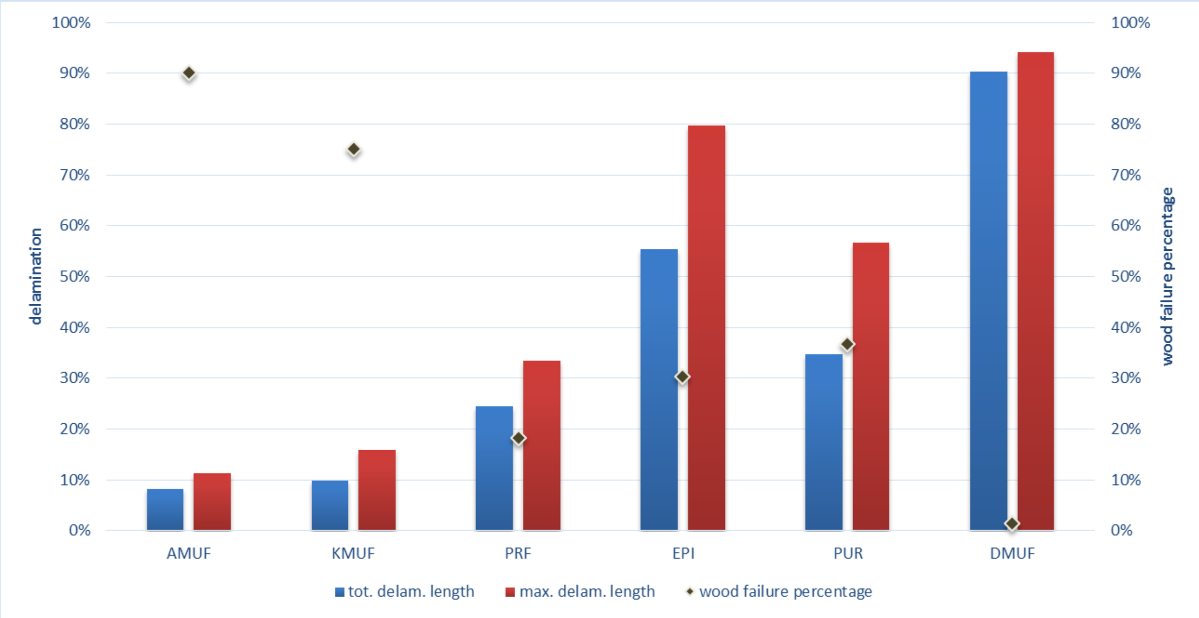


Fig. 1: Delamination and wood failure percentage

The results show that only AMUF and KMUF conformed with FprEN 16351, with total delamination lengths under 10% and maximum delamination lengths under 40%. However, both glues also produced samples which did not meet the requirements for delamination or wood failure percentage. Based on these results, we initiated a second series of tests to optimize the gluing process, in which the parameters of gluing, such as glue spread, assembly time, applied pressure and pressing time were manipulated. The results of this second experiment represent a further step in the optimization of the gluing process towards the goal of developing a functional joint bonding process for beech wood.

REFERENCES

BAYERISCHE STAATSFORSTEN (2011) Waldbauhandbuch.

FPREN 16351 (2013) Timber structures – Cross laminated timber – Requirements.

OHNESORGE, D., RICHTER, K., BECKER, G., AICHER, S., (2008) Adhesion behaviour of glued laminated timber from European Beech. Enhancing Bondline Performance – Final Conference of COST E34 Bonding of Timber.

SCHMIDT, M., GLOS, P., WEGENER, G., (2010) Verklebung von Buchenholz für tragende Holzbauteile. European Journal of Wood and Wood Products.

Potential of computer tomography in sawmills – value optimization for processing high grade logs

S. Dworak[1], M. Riegler[1], C. Hansmann[1], U. Müller[2]

[1] Competence Centre for Wood Composites and Wood Chemistry, Altenberger Strasse 69, 4040 Linz, Austria, s.dworak@kplus-wood.at

[2] Institute of Wood Science and Technology – Department of Material Science and Process Engineering – University of Natural Resources and Life Science, Konrad Lorenzstrasse 24, 3430 Tulln, Austria

Keywords: break-even analysis, flow sheet simulation, overrun, potential assessment

ABSTRACT

Introduction

For the production of high grade timber, it is necessary to detect various wood features such as knots, starting decay, resin pockets, cracks and the annual ring alignment. The introduced project investigates the potential of detecting these features consistently by means of high speed X-Ray computer tomography (CT).

Some high speed CT scanners are already implemented in softwood sawmills and operate successfully. Based on that, the basic idea of this project is to evaluate the level of value improvement of high grade hard- and softwood timber. Additionally, the effect of implemented CT technology on subsequent manufacturing processes is determined by simulating the material flow. The first part of the project of evaluating the state of the art in CT technology is presented in the study at hand.

Materials and methods

In the present study, a literature review with respect to CT-technology was carried out in various research and industrial fields. Additionally, experts in CT-technology were interviewed regarding current and future developments. As medical engineering is rather evolved in the field of CT, experts in this field were approached.

Results and Discussion

Numerous studies on the use of CT in the timber industry have been performed in the past few years. In especially, the grading of boards according to quality characteristics (ALMECIJA ET AL 2013), the scanning of whole logs with automatic detection of specific wood features (i.a. JOHANSSON ET AL 2013) as well as the possible economic potential of the additional information acquired from the logs were investigated (i.a. STÄNGLE ET AL 2014). As result, CT has proven to be an adequate method to detect wood features in logs. However not all required data can be extracted automatically and some cannot be extracted at all. Progress was especially achieved on the detection of knots. Annual ring alignment and decay are particularly challenging (WEI ET AL 2011). Furthermore the results presented cannot be applied unconditionally to all types of wood. Comparatively few studies were performed on hardwoods. Additionally, most of the conducted studies used data generated by medical CT scanners, which tend to use higher resolutions than industrial scanners. Due to the development of the first 3D industrial scale log scanner (GIUDICEANDREA ET AL 2011), the required adaptation of algorithms for low resolution CT was investigated (i.a. JOHANSSON ET AL 2013).

As scanning speed, resolution and radiation dose are directly linked, industrial applications may benefit from the efforts to reduce radiation dose in medical applications. Studies on

Compressive Sampling for Cone Beam CT showed a possible reduction in the number of required sampling by a factor of 3 to 5 (HU ET AL 2014). For multi-detector CT, improvements of resolution up to factor 2 could be achieved without modifying the hardware. Ultra Low Dose CT (ULD-CT) in combination with model-based iterative reconstruction (MBIR) shows sufficient quality for specific medical characterizations (NEROLADAKI ET AL 2013).

Conclusion

CT is an adequate analytical method for detecting wood features in logs processed in the timber industry. As research in CT technology is progressing, higher feed speeds and resolutions will be possibly realized soon. Beside the improvement of hardware, adequate signal transformation and image analysis might play a major role for detecting wood features in future.

Acknowledgment

The project, funded by the Austrian Research Promotion Agency, is conducted in cooperation with the international partners MiCROTEC (producer of log scanners), B. Keck GmbH and Schaffer Holzexport (midsized sawmills) and two institutes from BOKU University.

REFERENCES

ALMECIJA, B. CHOFFEL, D., DAQUITAINE, R., BOMBARDIER, V., AND CHARPENTIER, P. (2013) Economical interest of a x-rays vision system in a planing mill production chain. Journal of Physics: Conference Series, 416(1).

GIUDICEANDREA, F., URSELLA, E., AND VICARIO, E. (2011). A high speed ct scanner for the sawmill industry. 17th International Nondestructive Testing and Evaluation of Wood Symposium, Sopron, Hungary.

HU, Z., LIANG, D., XIA, D., AND ZHENG, H. (2014). Compressive sampling in computed tomography: Method and application. Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 748:26–32.

JOHANSSON, E., JOHANSSON, D., SKOG, J., AND FREDRIKSSON, M. (2013). Automated knot detection for high speed computed tomography on pinus sylvestris l. and picea abies (l.) karst. using ellipse fitting in concentric surfaces. Computers and Electronics in Agriculture, 96:238–245.

NEROLADAKI, A., BOTSIKAS, D., BOUDABBOUS, S., BECKER, C., AND MONTET, X. (2013). Computed tomography of the chest with model-based iterative reconstruction using a radiation exposure similar to chest x-ray examination: Preliminary observations. European Radiology, 23(2):360–366.

STÄNGLE, S., BRÜCHERT, F., HEIKKILA, A., USENIUS, T., USENIUS, A., AND SAUTER, U. (2014). Potentially increased sawmill yield from hardwoods using x-ray computed tomography for knot detection. Annals of Forest Science, pages 1–9.

WEI, Q., LEBLON, B., AND LA ROCQUE, A. (2011). On the use of x-ray computed tomography for determining wood properties: A review. Canadian Journal of Forest Research, 41(11):2120–2140.

A METHOD FOR TOPOCHEMICAL INVESTAGATION OF FURFURYLATED MAPLE

G. Ehmcke[1], A. Pilgård[2], G. Koch[3], K. Richter[4]

[1] Chair of Wood Science - Technische Universität München, Winzererstrasse 45, D-80797 München, Germany, E-Mail: ehmcke@hfm.tum.de

[2] Dr. Chair of Wood Science -Technische Universität München, Winzererstrasse 45, D-80797 München, Germany; Wood Technology, SP Technical Research Institute of Sweden, BOX 857, SE-501 15, Borås, Sweden, E-Mail: annica.pilgard@sp.se

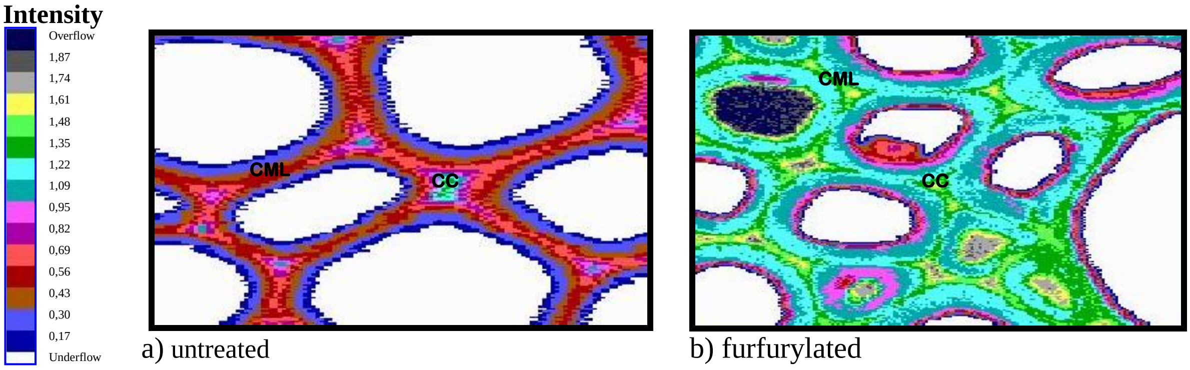
[3] Dr. Thünen Institute of Wood Research, Leuschnerstr. 91, D-21031 Hamburg, Germany, E-mail: gerald.koch@ti.bund.de

[4] Professor, Chair of Wood Science and Wood Research Munich, Technische Universität München, Winzererstrasse 45, D-80797 München, Germany, E-mail: richter@hfm.tum.de

Keywords: UV microspectrophotometry, Modified wood, Furfuryl alcohol, Lignin modification

ABSTRACT

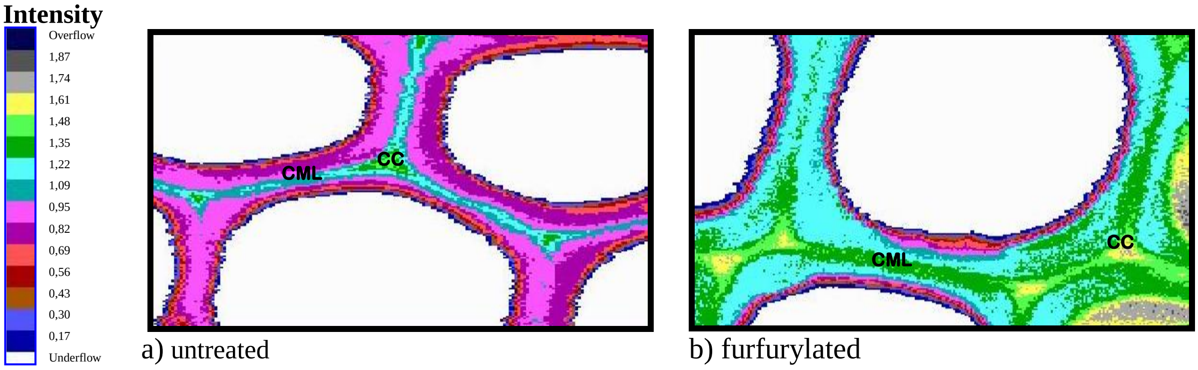
Wood applications in building and construction are faced with varying environmental conditions. Technical failure is frequently initiated by wood decaying fungi. Wood modification involves the action of a chemical, biological or physical agent upon the material, resulting in increased durability (HILL 2006). In contrast to treatments with traditional wood preservatives, where the resistance is caused mainly by the toxicity of the chemicals added, little is known about the mode of action of modified wood. Furfurylation of wood is a chemical modification where furfuryl alcohol penetrates into the wood cell wall polymerizes *in situ* resulting in a permanent swelling of the wood cell wall (STAMM 1977). This leads to higher durability against biodegradation (LANDE ET AL. 2004). A previous study indicates that furfuryl alcohol can bind to a lignin model compound (NORDSTERNIA 2008) but if this reaction occurs in solid wood is still unclear. UV microspectrophotometry (UMSP) is ideally suited to study the topochemical distribution of lignin in the wood cell wall (FERGUS ET AL. 1969; SCOTT ET AL 1969; SAKA ET AL. 1982; FUKAZAWA 1992; KOCH AND KLEIST 2001; KOCH AND GRÜNWALD 2004). The UMSP technique enables direct imaging of lignin modification within individual cell wall layers. The aim of this study was to develop a method to investigate furfurylated wood for a better understanding of the furfuryl alcohol polymerization process in the wood cell wall. Three different furfurylation treatments of maple (*Acer* spp.) and pine (*Pinus radiata*) were investigated. The samples were dehydrated in a graded series of ethanol, afterwards embedded in epoxy resin according to Spurr (1969), sectioned with an ultramicrotome, and transferred to quartz microscopic slides. The semithin sections (1µm), with a size of approximately 0.5 mm², were immersed in non-UV absorbing glycerine and covered with a quartz cover slip. The topochemical analyses of the untreated maple and radiate pine samples show a typical profile of lignin distribution (Figs. 1a and 2a). The colour pixels represent the intensity of UV absorbance at wavelength of λ_{278nm} for hardwood and at λ_{280nm} for softwood. In Figs. 1b and 2b, two-dimensional scanning profiles of furfurylated maple and radiate pine are shown. Compared with the untreated samples, the furfurylated samples show significant higher absorbance values within the complete cell wall. The results indicate that cellular UV microspectrophotometry is a well suited method to study early fungal degradation damages in the cell wall of furfurylated wood. With this method it might also be possible to study potential bindings of furfuryl alcohol to the cell wall macromolecules on a subcellular level.



a) untreated b) furfurylated

compound middle lamella (CML), cell corner (CC)

Figure 1: Representative UV microscopic scanning profiles of maple



a) untreated b) furfurylated

compound middle lamella (CML), cell corner (CC)

Figure 2: Representative UV microscopic scanning profiles of radiate pine

REFERENCES

FERGUS, B.J. ET AL. (1969): The distribution of lignin in sprucewood as determined by ultraviolet microscopy. *Wood Science and Technology*, **3**(2), 117–138.

FUKAZAWA K (1992): Ultraviolet microscopy. In: Lin, S.Y., Dence, C.W. (Eds.) *Methods in lignin chemistry*. Springer, Berlin, 110–121.

HILL, C. (2006): Wood Modification: Chemical, Thermal and Other Processes. In: Stevens, C.V. (Ed.), John Wiley and Sons, Ltd, England, 239 p., 19–44.

KOCH, G.; GRÜNWALD, C. (2004): Application of UV microspectrophotometry for the topochemical detection of lignin and phenolic extractives in wood fibre cell walls. In: Schmitt, U. et al. (Eds.) *Wood fibre cell walls: methods to study their formation, structure and properties*. Swedish University of Agricultural Sciences, Uppsala, 119–130.

KOCH, G.; KLEIST, G. (2001): Application of scanning UV microspectrophotometry to localise lignins and phenolic extractives in plant cell walls. *Holzforschung*, **55**(6):563–567

LANDE, S.; WESTIN, M. AND SCHNEIDER, M.H. (2004): Eco-efficient wood protection: Furfurylated wood as alternative to traditional wood preservation. *Management of Environmental Quality: An International Journal*, 15(5), 529–540.

NORDSTIERNA, L. ET AL. (2008): Towards novel wood-based materials: Chemical bonds between lignin-like model molecules and poly(furfuryl alcohol) studied by NMR. *Holzforschung*, **62**(6): 709–713.

SAKA, S. ET AL. (1982): Comparative studies on lignin distribution by UV microscopy and bromination combined with EDXA. *Wood Science and Technology*, **16**(4): 269–277.

SCOTT, J. ET AL. (1969): The application of ultraviolet microscopy to the distribution of lignin in wood: description and validity of the technique. *Wood Science and Technology*, **3**(1): 73–92.

SPURR, A.R. (1969): A low viscosity epoxy resin embedding medium for electron microscopy. *Journal of ultrastructure research*, **26**:31–43

STAMM, A.J. (1977): Dimensional Stabilization of Wood with Furfuryl Alcohol Resin. In: *Wood Technology: Chemical Aspects*. Goldstein, I. (Ed.) ACS Symposium Series, **43**(9):141–149.

Imaging Hardwoods with SilviScan

R. Evans

CSIRO Materials Science and Engineering, Bayview Avenue
Clayton, Victoria 3168, Australia. robertxevans@gmail.com

Keywords: SilviScan, hardwood, imaging, transmitted light, reflected light, image analysis

ABSTRACT

SilviScan is a system of connected instruments designed for the rapid automated analysis of wood microstructure in samples cut from (for example) increment cores. The system has been used as the basis of at least 500 projects in 20 countries. One of the SilviScan modules is an optical image analyser employing a combination of reflected and transmitted light from LEDs to reveal the cell cross-sections in polished transverse surfaces (wood fibre secondary walls are relatively efficient light conductors). Radial sequences of images are automatically acquired and stitched together for determination of cell cross-sectional dimensions averaged over 25 micron intervals (for example). The current generation (SilviScan-3), developed in 2000-2003 and installed in Australia, Sweden and Canada, uses short wavelength LEDs for reflected light imaging and long wavelength LEDs for transmitted light imaging. The use of transmitted light imaging of wood was invented a decade earlier for SilviScan-1. It was found in 1990 that high contrast images of cell cross-sections in polished wood transverse surfaces could be obtained using transmitted light from a tungsten source transmitted along the wood cells acting as fibre optic conductors, but only longer wavelengths made it through thick samples and that LEDs could supply sufficient intensity (EVANS 1994). SilviScan-1 therefore used high intensity red LEDs for both transmission and reflection. SilviScan-2 used green for reflection and red for transmission. SilviScan-3 has interchangeable lighting systems and objective lenses, allowing a range of wavelengths and magnifications. The upper end of the wavelength range is determined in practice by the spectral sensitivity of the lenses and CCD camera, and the required spatial resolution.

For hardwood species such as poplar, beech, birch and alder, common in the Northern hemisphere, red/infrared wavelengths down to about 640nm are usually transmitted efficiently. Other species, such as eucalypts require the longer wavelengths. We have used LEDs in the wavelength range 640-940nm in transmission and 450nm to 940nm in reflection. SilviScan has also used various cameras ranging from 0.3Mpixels 6.0Mpixels, with interchangeable objectives giving typical pixel sizes in the range of about 0.3-2.5 microns. This paper presents images taken in reflected and transmitted light for a range of species and magnification. Some examples from SilviScan are given in Figs 1-3 for three hardwoods. These images are 0.65mm high and contain ~ 1400 x 1000 pixels. The transmitted light (wavelength 450nm) and reflected light (880nm) images were acquired in pairs at the same position within each sample. Transmitted light images are more easily analysed because of the improved contrast. A softwood (Douglas fir) is shown in Fig 4 for comparison.

REFERENCE

EVANS R. (1994) Rapid measurement of the transverse dimensions of tracheids in radial wood sections from *Pinus radiata. Holzforschung* 48 (2):168-172.

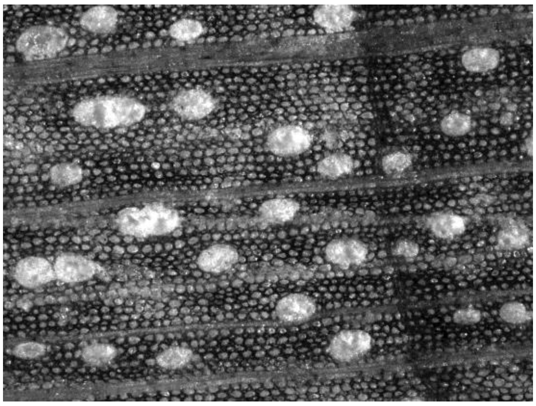


Figure 1a: Maple in reflected light.

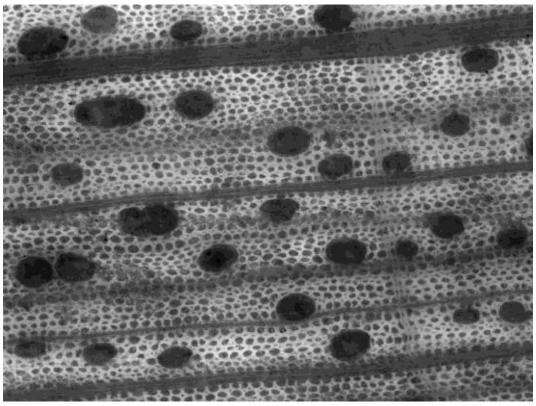


Figure 1b: Maple in transmitted light.

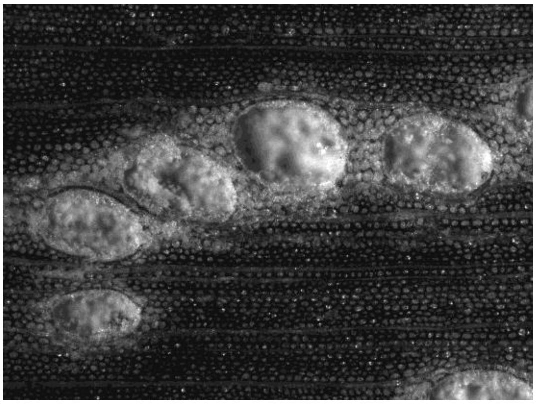


Figure 2a: Eucalypt in reflected light.

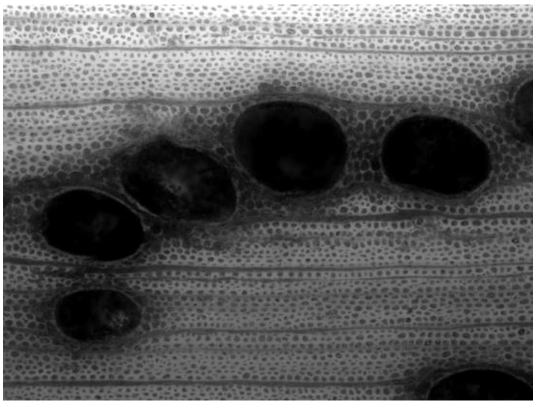


Figure 2b: Eucalypt in transmitted light.

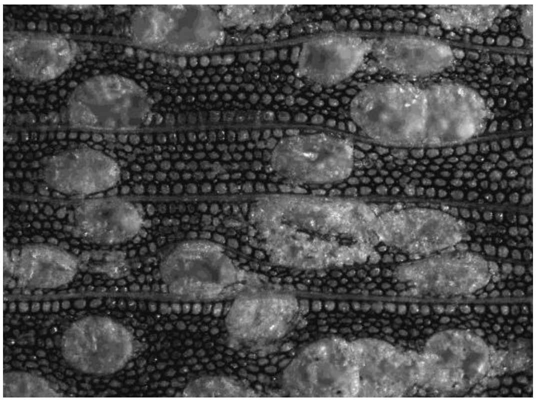


Figure 3a: Birch in reflected light.

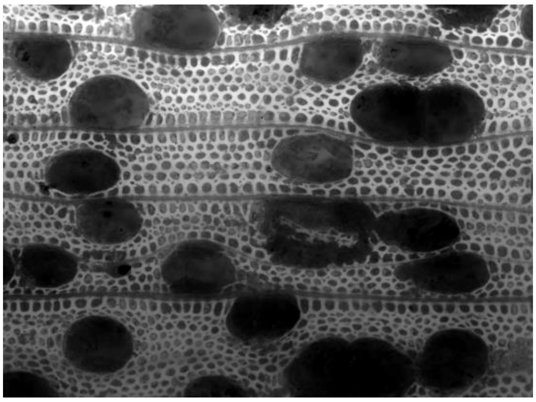


Figure 3b: Birch in transmitted light.

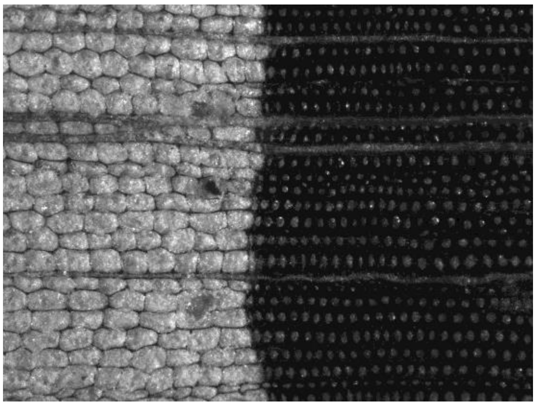


Figure 4a: Douglas fir in reflected light.

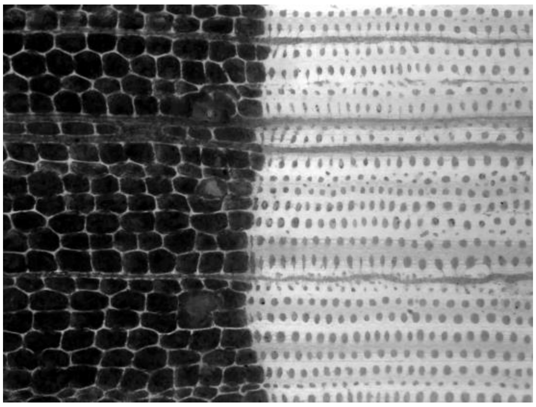


Figure 4b: Douglas fir in transmitted light.

Ultra High Performance Plywood (UHPP) – A Feasability Study on Veneer-based I-beams

M.Grabner[1], T. Bogensperger[1], G. Schickhofer[1]

[1] Inffeldgasse 24/I, 8010 Graz, Austria, Institute of Timber Engineering and Wood Technology –

Graz University of Technology, markus.grabner@tugraz.at, thomas.bogensperger@tugraz.at, gerhard.schickhofer@tugraz.at

Keywords: birch, plywood, laminated veneer lumber, bending strength, light weight structure, Ultra High Performance Plywood

ABSTRACT

The present demand of sustainable energy sources and building materials leads to a high competitive market for all wood-working industries. In the situation of diminishing resources, the interest for new technologies and applications due to efficient and economic utilization of wood is growing. In this context it has to be scrutinised, if using medium and low quality hardwood logs for energy purpose can be justified. Concerning cascade utilization, a lot of hardwood species show high mechanical and physical properties which make them applicable for structural purposes. In our paper we present a new method of hardwood utilization named as Ultra High Performance Plywood (UHPP). UHPP means combining and moulding veneers for creation of light weight structural elements. Our paper illustrates a feasibility study on a UHPP light-weight structure element: the UHPP_I_beam.

The UHPP_I_beam is a linear member with an I-shaped cross section. The use of veneer allows us to design a connection between the two components flange and web without weakening the flanges by finger-joints. Fig. 1 illustrates the cross-section, the layer-setup with two grain directions (0°, 90°) related to the beam axis and the main production steps to fabricate a specimen and investigate its load bearing behaviour.

On a first approach the moulding and bonding process to create two C-sections are performed by a vertical hydraulic press with. The different layers are placed in a rigid frame as seen in Fig. 1. During the pressing the two form-elements with a defined curvature slide on a trapeze-shaped element (a), moulding the veneer layup consisting of three unidirectional veneers (α = 0°). Simultaneous these veneer layers are bonded together with the filler-element and the transversal layer (α = 90). Finally the C-sections and flanges are assembled resulting in an I-shaped cross-section. Two I-beams (A and B) with a length of L = 3000 [mm] were produced.

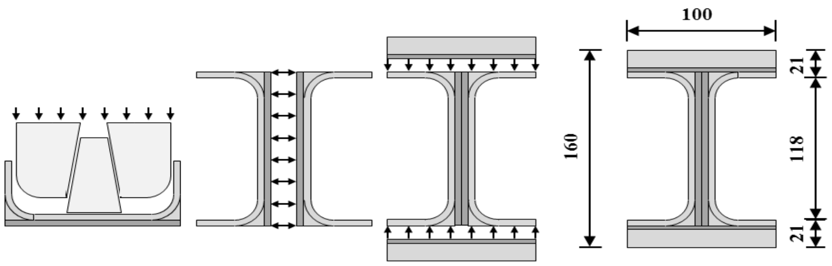


***Figure 1:** (a) moulding C-section, (b) assembling web, (c) assembling flanges, (d) geometry*

To investigate bending capacity and load bearing behaviour a four-point bending test was carried out according to EN 408 (2012). The first test was performed to determine the ultimate load. In addition the global midspan deformation was recorded. The second test comprised the measurement of the local and global midspan deformation. To analyse the load bearing behaviour of the composite structural element (length L = [3000 mm]) a model, considering stiffness parameters of each cross-section component was set up. The required parameters were determined by extracting small specimens of the tested I-beams. Shear, tension and compression tests were conducted. Table 1 provides the main results of the experimental tests.

Table 1: Results of 4-point bending tests

Specimen [-]	F_{max} [N]	$w_{0.4}$ [mm][a]	$w_{0.1}$ [mm][a]	EI [Nmm²][b]	GA/κ [N][c]
A	31736	18.32	4.26	2.81E+11	-
B	29359	16,32	3,85	2.39E+11	2,56E+06

[a]global midspan deflection, [b]bending stiffness, [c]shear stiffness

We observed a ductile load bearing behaviour related to local buckling of veneers in the compression zone (see Fig. 1). The initial failure of the specimens occurred in the mid span area.

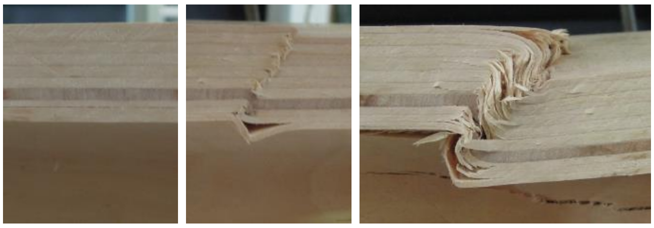


Figure 1: initial failure: stability failure of veneers on the upper flange

To sum up the main findings are:
- ductile load-bearing behaviour,
- stability failure related to a local buckling of veneers in the compression area, and
- moulding and gluing process lead to local delamination of veneers in these areas.

The next steps to achieve higher load bearing performance of UHPP are to optimize the production process and to change geometry parameters (layer-setup, web and flange dimensions) based on the mentioned model.

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REFERENCES

EN 408 (2012) Timber structures - Structural timber and glued laminated timber - Determination of some physical and mechanical properties.

BENOIT, P.G., HANCOCK, S.B., BAILLERES, H. (2014) Thin-Walled Timber Structures. In: RILEM Bookseries Volume 9, Materials and Joints in Timber Structures

European Conventions for Measurement of Dry Film Thickness of Coatings on Coarse Porous Hardwood Species

G. Grüll[1], P. Svane[2]

[1] Holzforschung Austria, Franz Grill Strasse 7, 1030 Vienna, Austria, g.gruell@holzforschung.at

[2] Coating Consultancy, Akacievej 2A, DK-2640 Hedehusene, Denmark, ps@overflade.dk

Keywords: wood coating, film thickness, vessel, micro structure

ABSTRACT

As a substrate for coatings wood surfaces have to be considered as rough compared to other materials such as metals or plastics. Hence, measurements of dry film thickness of coatings on wood usually lead to larger variance of results. This is particularly the case for coatings on coarse porous hardwood species such as robinia, oak, ash, chestnut, meranti and many others. With these wood species open vessels on the longitudinal surfaces lead to large variations in actual coating film thickness and the difficulty to choose positions and directions for thickness measurements under the microscope. Present standards for measurement of coating film thickness (ISO 2808, EN 927-3) provide no guidance how to measure at vessels on the surfaces of coarse porous wood species.

In a European Round Robin trial involving 11 laboratories different strategies and methods for measurement of dry film thickness of coatings on spruce, beech and meranti wood were used and compared. This included microscopic measurements at randomly selected positions, analysis of micoroscopic images with area assessment and non-destructive ultrasonic measurements. From the results of microscopic measurements according to ISO 2808 it was concluded that variations in results were larger on the meranti samples (Fig. 1) compared to all other wood species.

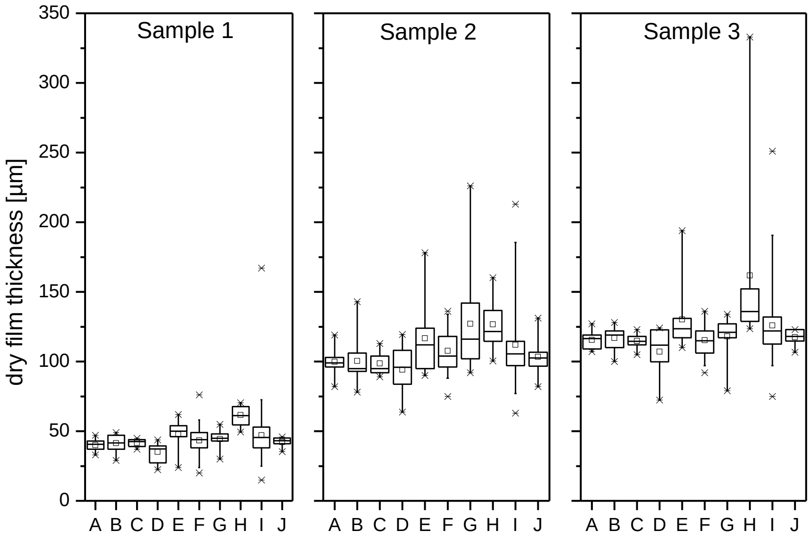


Figure 4: Results of micorscopic dry film thickness measurements in 10 laboratories (A-J) on 3 samples of coated meranti wood

The individual selection of measurement positions on micrographs of open vessels on the coated meranti surfaces revealed great differences in measurement strategy between the labs

(Fig. 2). Lab D measured minimum coating film thickness at the edge of the open vessel. Most of the other labs did not include the open vessels filled with coating material but selected measurement positions beside these vessels (e.g. lab A). Lab E selected a measurement position in the centre of the open vessel whereas lab G selected a position not in the centre of the vessel but in the middle of the pencil mark that defined the measurement position.

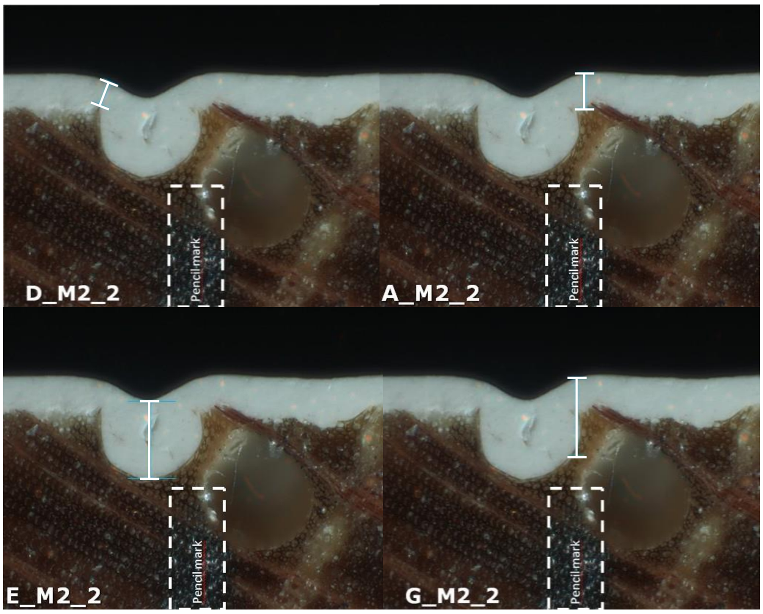


Figure 5: Individual selection of measurement positions on micrographs of open vessels on the coated surface of meranti wood; examples from four different laboratories (D, A, E and G)

Based on these results the committee CEN/TC 139/WG2 "Coating Systems for Wood" agreed on conventions for measurements at open vessels and drafted an improved method description to minimize deviations of results between labs. On hardwoods with coarse pores measurements shall be taken beside open vessels on the wood surface (Fig. 3). Positions where the coating material penetrated open vessels may not be included in the measurements. No matter where the measurement is scheduled, coating material that has penetrated into open vessels may not be included. Measurements have to be oriented perpendicular to the test surface of the wood sample. It is intended to bring these conventions forward to ISO standardisation.

Figure 6: European convention to take measurements beside open vessels, coating material that has penetrated into open vessels may not be included; upper arrow marks randomly selected position

REFERENCES

EN 927-3 (2006) Paints and Varnishes - Coating materials and coating systems for exterior wood –Part 3: Natural weathering test

EN ISO 2808 (2007) Paints and varnishes – Determination of film thickness

ACADEMY PHD AWARDS WINNER'S PRESENTATION

Transforming Lignocelluloses to Sugars and Liquid Fuels

Li Shuai

Department of Biological Systems Engineering, University of Wisconsin-Madison, 460 Henry Mall, Madison, WI, 53706, United States, shuailiuw@gmail.com

Keywords: Lignocelluloses, sugar, liquid fuel

ABSTRACT

Extensive research has been done on the development of biofuel from low-cost and abundant lignocelluloses. Unfortunately, cost-effectively producing sugars and sugar derivatives still remains a barrier to developing a biorefining industry. In order to overcome this barrier, a few innovative processes were developed for converting lignocelluloses into sugars and liquid fuels.

First, a sulfite pretreatment (SPORL–Sulfite Pretreatment to Overcome Recalcitrance of Lignocelluloses) was demonstrated to be more effective to enhance enzymatic digestibility of woody biomass like spruce than dilute acid pretreatment (DA). Addition of sulfite along with sulfuric acid partially dissolved lignin and sulfonated residual lignin in the SPORL substrate, which reduced non-productive adsorption of enzymes on lignin. The buffer effect of sulfite protected cellulose and hemicellulose from extensive acidic hydrolysis and further decomposition. Therefore, SPORL recovered more fermentable sugars and generated less fermentation inhibitors than DA pretreatment.

Second, a polystyrene-based cellulase-mimetic solid acid with both cellulose binding domain (-Cl) and catalytic domain (-SO_3H) was synthesized for cellulose hydrolysis. The binding domain facilitated the association of substrate onto the catalyst surface and therefore accelerated the cellulose hydrolysis. The cellulose hydrolysis catalyzed by the solid acid had much lower apparent activation energy than the ones catalyzed by liquid acids and general solid acids without binding domains.

Third, a one-step process was developed for direct saccharification of lignocelluloses at moderate temperature in concentrated metal halide solution without pretreatment. Fed-batch of biomass allowed to produce a concentrated sugar solution for downstream processing. Sugars and the salt were separated through a combination of solvent extraction of salt and ion-exchange chromatography or other techniques.

Fourth, a one-pot process was developed for transforming lignocellulose into furan-based precursors for hydrocarbon fuels without pretreatment or saccharification. In a LiBr/acetone system with small amount of acid, unsolvated Li^+ and Br^- rapidly disrupted hydrogen bonds in cellulose crystals and facilitated the hydrolysis of cellulose and hemicellulose. Br^- further catalyzed the dehydration of sugars into hydroxymethylfurfural (or furfural), which subsequently reacted with acetone through aldol-condensation to form furan-based precursors with 5-21 carbons in high yield and selectivity. Lignin was extensively depolymerized into low-molecular-weight fragments that can be hydrodeoxygenated together with the precursors into hydrocarbon fuels. The lignin also had good potential for high-value co-products development.

SESSION V
INDUSTRIAL APPLICATIONS

3D-cutting force analysis of hardwoods compared to softwoods

T. Krenke [1], S. Frybort[2], U. Müller[3]

[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

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

[3] Institute of Wood Science and Technology – Department of Material Science and Process Engineering – University of Natural Resources and Life Science, Konrad Lorenz Strasse 24, 3430 Tulln, Austria, ulrich.mueller@boku.ac.at

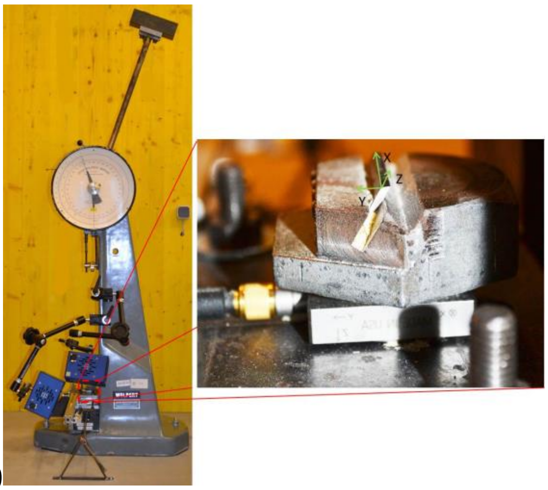
Keywords: Cutting force analysis, transmission function, wood properties, beech

ABSTRACT

Mechanical disintegration is one of the key processes in the woodworking industry. The reduction of saw kerf width as well as improvement of surface quality is becoming increasingly important, which is especially true for high value hardwoods. However, an optimisation of the cutting processes requires a basic understanding of the interaction of tool and workpiece. For this reason a complete physical description of the cutting process is needed. Subsequently, out of this analytical description an applicable semi-empirical model, likewise in the metal working industry, will be developed. The validation of a cutting force model requires the existence of consistent cutting force values. However, utilization of data from previous studies is impossible as important information about data processing, cutting parameters as well as wood properties is lacking. To enable a validation of the cutting force model a standardized and reliable method for the examination of cutting forces had to be developed. Therefore a pendulum was modified and equipped with an adjustable machine table to enable examination of different cutting thicknesses. For force measurement a force-sensor based on the piezoelectric effect, enabling force measurement of high resolution in three directions, was mounted between machine table and knife holder. The main focus of this work was lying on the development of data handling and subsequent data processing procedure as well as on a standardization of sample geometry, knife geometry, knife properties, knife alignment and cutting parameters.

The aim of this work is the development of a general method for a basic analysis of dynamic cutting processes. For cutting force measurements a modified pendulum (Wolpert, Vienna, Austria) with cutting speeds of around 7 m/sec was used (Fig. 1a). Therefore the sample was mounted onto the hammer which is passing the knife at the bottom dead centre of the pendulum. The force sensor is mounted beneath the knife holder measuring the occurring forces in three directions by the piezo-electric effect (KRENKE ET AL. 2014). Generally, measured data are highly influenced by the chosen test set-up as well as by subsequent data processing. For this reason results of former studies and their derived models are not transferable (PAHLITZSCH 1962, MARTYENKO 2006, GOLI 2005). The frequently observed method of curve smoothing by moving average is not practicable as important material-specific information is lost (ETTELT 2004, HEISEL 2001). To achieve unadulterated data the saved output signal was filtered by the so-called system/transfer-function. The system/transfer-function considers all influencing components of the test-setup as a black box whereby the relationship between input- and output-signal is described by the

frequency response function. Therefore the output signal is processed by the frequency response function eliminating all disturbing influences from signal acquisition.
For examination of the influence of varying wood properties, e.g. moisture content, fibre angle and density on the cutting process solid samples of flawless beech (*Fagus sylvatica*) of differing fibre angles (0° and 45°) were used. Sample geometry is shown in Fig. 1b.
Cutting force is about 30% higher for 45° fibre angle compared to 0°. Measurements also show that the amplitude of the curve is influenced by the density.

a) 

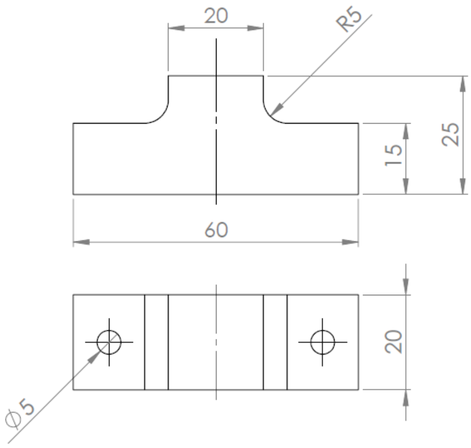
b) 

Figure 7a: modified pendulum and force sensor (KRENKE ET AL. 2014); b: sample geometry

REFERENCES

KRENKE, T., FRYBORT, S., VAY, O. MÜLLER, U. (2014) A new method of dynamic 3D-cutting force analysis of wood. In: Proceedings of the 57th International Convention of Society of Wood Science and Technology, Zvolen, Slovakia, pp.47-52.

ETTELT B., GITTEL H.-J. (2004) Sägen, Fräsen, Hobeln, Bohren; Die Spanung von Holz und ihre Werkzeuge. 3rd Edition: DRW-Verlag, Leinfelden-Echterdingen.

GOLI G., FIORAVANTI M., SODINI N., JIANGANG Z., UZIELLI L. (2005) Wood Processing: a contribute to the interpretation of surface origin according to grain orientation. 17th International Wood Machining Seminar, Rosenheim, Germany.

HEISEL U., TRÖGER J. (2001) Aktueller Handlungsbedarf zur Bestimmung der Kräfte am Schneidkeil (2). HOB Die Holzbearbeitung **47**: 72 - 76.

MARTYENKO S., SCHOLZ F., TRÖGER J. (2006) Modellierung der Kräfte am Schneidkeil. Holztechnologie **47**: 32-38.

PAHLITZSCH G (1962) Internationaler Stand der Forschung auf dem Gebiet des Sägens. Holz als Roh- und Werkstoff **20**: 381-392.

Utilisation of Robinia Wood - properties, products, resources

R. Németh[1], S. Molnár[2], J. Ábrahám[3], S. Komán[4], D. Csordós[5], K. Csupor[6], M. Bariska[7]

[1,2,3,4,5,6] Institute of Wood Science – University of West Hungary – H-9400 Sopron, Bajcsy-Zs. U. 4. Hungary,
robert.nemeth@skk.nyme.hu

[7] Eidgenössische Technische Hochschule, Zürich, Switzerland – retired professor,
embariska@bluewin.ch

Keywords: Robinia pseudoacacia L., black locust, durability, hardwood

ABSTRACT

Robinia, or black locust in many countries simply called 'acacia'. This misleading name leads to misunderstandings as people may mistake it for the real acacia species (genus Acacia), growing in subtropical and tropical regions (MOLNÁR and BARISKA, 2006).

Together with many other plants, locust has been introduced to Europe from North America by J. Robin, the royal chief gardener of Paris in 1601. Today, 24% the Hungarian forests (plantations) is made up of black locust, and no other European country has as much of it as Hungary does (463,000 ha). Romania, Italy, France, Serbia, Bulgaria, Slovakia and the Ukraine also have large stands of black locust. Presently, black locust forest areas shows fast expansion in China and South Korea.

In Hungary, about 8,500 ha of black locust forests are harvested annually. The growing stock in Hungary amounts to 46,8 M m^3, the annual harvesting is (including intermediate cutting) was around 1.5-1.9 million m^3 for the past few years. The annual increments amounts to 3,2 M m^3. The rotation period varies with the quality of the stands, the average being 31 years.

Fig. 1.: Microscopic (left) and macroscopic (right) structure of Robinia

The following assortments are produced: sawlogs, lower quality (short) logs, mine timber, masts, poles, chips, firewood. Only about 18-20% of the harvest is suitable for sawnwood.

As softwoods were short in Hungary, and the import of it was restricted, Hungarian wood scientists and engineers developed glulam-structures of Robinia wood. Some of these structures are still in service longer than 40 years.

According to the international standard EN 350-2, black locust is the only European species that can be put into the durability class 1-2. Because it does not require chemical treatment for outdoor applications, black locust can be considered a very environment-friendly material.

Black locust develops relatively straight, cylindrical trunks in closed stands. The cultivation of special strains, like the straight "shipmast locust" variety, increasingly get greater attention. In the frame of a new project: “Developing the industrialized vegetative propagation technology and the plantation model for new, extraordinary fast growing "OBELISK" Robinia varieties for high quality logs” foresters and wood scientist are working together to enlarge the available wood resources with shorter rotation periods (below 20 years) and higher yields.

During the last decades several research programs were completed or are still running in Sopron: Technology for high Quality Products from Black locust – EU INCO-COPERNICUS Project; Physical and anatomical properties of selected fast-growing robinia variety candidates – OTKA (National); Specific properties of the juvenile wood of domestic hardwood species – OTKA (National); Enhancing the durability and dimensional stability of domestic hardwoods through thermal treatment - OTKA (National); GOP EU-cofinanced project „Obelisk” and „Turbo” varieties

In the frame of the above mentioned projects innovative product groups were defined (parquet, window scantlings, furniture), growing rates, physic-mechanical properties were characterised, furthermore glue ability and paint ability with different systems were tested. The calorific values (Heartwood/Sapwood/Bark), the durability against wood destroying fungi and colour variations were measured and characterised.

Newly running investigations are dealing with the thyloses forming, “black stripe” discolouration and durability-colour correlations. Tests of remaining load bearing capacities of “old” Robinia glue-lam structures are running too.

Robinia growers and honey producers are facing EU regulation issues, as Robinia is classified as invasive and alien species, and thus its distribution should be limited. As a reaction to this disadvantageous regulation the national authorities supported by plantation owners, research organisations, and related associations established the so called “Coalition for Robinia”. This initiative should help to show the ecological and economic benefits of Robinia plantations and the utilization of the wood in a holistic approach.

REFERENCES

MOLNÁR, S., BARISKA, M. (2006) Magyarország ipari fái / Wood species of Hungary, Published by Szaktudás Kiadó Ház Zrt. Budapest, pp. 62-65, ISBN 963 9553 96 4

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This study was supported by the Project: GOP-1.1.1-11-2012 “Developing an industrialized vegetative propagation technology and the plantation model for new, extraordinary fast growing "OBELISK" Robinia varieties for high quality logs” GOP-1.1.1-11-2012-0084 project, sponsored by the European Regional Funds (EU) and the New Széchenyi Plan (Hungary).

Comparison study of poplar and spruce light frame panels compression and shearing strength of paper

Z. Pásztory[1], P. Rébék-Nagy[1]

[1] University of West Hungary, Innovation Center, 4 Bajcsy Zs. Sopron, Hungary, 9400

Keywords: Poplar, spruce, frame wall construction, compression strength, shearing test

ABSTRACT

The majority of wood frame panels are made of pine, especially spruce and Scotch pine in Europe, although many countries have great population of poplar. This study investigates the possibility of using poplar instead of pine in lightweight house wall studs. Vertical compression test and cyclic lateral shearing test were done on full scale light frame panels. The poplar panels show unexpected strengths in compression and in shearing also. In case of compression the difference is no more than 6%, on shearing the poplar panels show more flexibility and lower deformation value during shearing cyclic, however the failure force was higher in case of spruce.

INTRODUCTION

Wood is a traditional building material due to its dimensional and mechanical properties and its other favorable features. There have been numerous studies that have investigated different aspects of the light frame buildings such as thermal properties, and durability or mechanical strength. Present study investigates the substitution of coniferous light frame panel elements to poplar, and its effect to the mechanical properties like vertical compression, and shearing capacity.

MATERIALS AND METHODS

Four panel were built using poplar (*Euramericana 'Pannonia'*) timber and four from spruce (*Picea Abies*) timber, also for compression and shearing test. The Pannonia poplar has a density of 410 kg/m^3 what makes it a good candidate as a construction material. The other reason this clone was chosen is its wide spread in Europe e.g. more than half of the hybrid poplar plantations are Euramericana in Hungary. The knots have less adverse effect on the strength of the poplar, as in case of spruce.

The panels had the dimensions at compression test: 120 mm frame thickness and 1250 mm width, 2500 mm height.

Figure 1 Compression test measuring position

The inner sheathing boards were OSB3-EN300-E1 with thickness of 15 mm and the exterior boards were 12 mm. The studs' cross section was

120 x 60 mm, 120 x 90 mm at the top plates and 120 x 70 mm at the bottom plates. The distance of vertical studs were 625 mm on-center spacing. The shearing panels had the same dimension, and materials except the length of the panel which was 3750 mm (three modules of compression specimens). Hydraulic Power Units with 0.001 mm displacement, 0.01 kN force accuracy, and 250 kN maximal load capacity were used for loading. During compression test two cylinder were used. (Figure 1)

RESULTS AND DISCUSSION

In the compression test the performance of the panels were examined under 100 kN, 200 kN, and the load leading to the panel failure. The main investigated parameters were the failure force, compression at the failure. Compression strengths of spruce panels were only 6% higher than the average of poplar panels. The compressive strain was 12.833 mm and 13.043 mm in spruce and poplar panels at the moment of break.
In the shearing test, the panels were twisting or shifting without a spectacular breakage of frames or OSB boards. The cyclical loads make the panel rather exhausted than break. Reaching the appropriate force in the given cycle it was hold for one minute then the actuator force decrease to zero again. By the consequence of the load the panels suffer some deformation, to a certain extent it is elastic and over a point it is permanent. Figure 2 shows the deformation of panels' average data. The increasing values between the peaks of the same loading level mean the worn effect of the panels, namely the same force caused higher displacement. The graph prove the spruce panels suffered higher deformations in all loading level and the failure deformation was higher than poplar panels also.

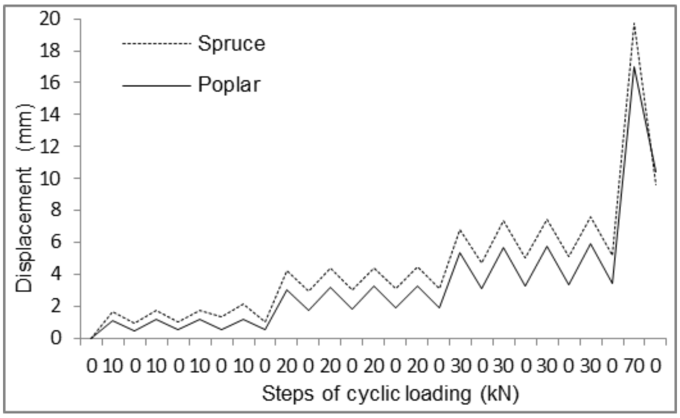

Figure 2 Average displacements of spruce and poplar panels

Failure force shows trifling advantage for spruce made panels. The displacement at the moment of failure proves that the poplar panels have the same stability having a 4.1% less failure displacement (the lower the better). Likewise the permanent deformation is lower after the last 30 kN load in case of polar panels. The results show that the spruce panels average have 51.3% higher permanent deformation what is significant difference. The poplar panels provide more flexible properties.
The shearing strength of poplar panels were higher and the small level of the deformation parameters of poplar panel are remarkable advantageous too. From the aspects of shearing stress the poplar can provide at least the same stability and higher flexibility than spruce panels. By this, it can be stated that the poplar could substitute the spruce frame elements.

ACKNOWLEDGEMENT

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Material use of plantation wood for higher value utilization after wood modification with renewable modification agents

P. Rademacher[1], D. Meier[2], T. Hofmann[3], P. Pařil[1], J. Baar[1], P. Sablík[1], P. Čermák[1], Z. Paschova[1], R. Rousek[1]

[1] Department of Wood Science - Faculty of Forestry and Wood Technology - Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic, peter.rademacher@mendelu.cz

[2] Thünen Institute of Wood Research, Leuschnerstr. 91B, 21031 Hamburg, Germany, dietrich.meier@ti.bund.de

[3] Institute of Chemistry - Faculty of Forestry - University of West Hungary - Ady Endre u. 5, 9400 Sopron, Hungary, hofmannt@emk.nyme.hu

Keywords: Plantation wood, native wood extracts, modification, impregnation, weight-percent-gain, durability, leaching

ABSTRACT

Introduction: In addition to wood production in natural forests, the establishment of plantations could help to increase the amount of available wood assortments. The production and utilization of renewable biomass especially from fast growing trees in short rotation plantations (SRPs) have increased over the past ten years and are important for a future biomass supply with also options for different usages. Because of low material properties due to the fast growing character or low wood-density and low incorporation of heartwood-substances, biomass from central European plantations is mainly used for energy applications. The first step for an increased material- and reduced energy-use of wood from fast growing plantations or also from lesser used wood species along the utilization chain is deepened knowledge about properties of native wood and their secondary improvement.

Wood modification process: Whereas in practical wood protection the use of biocides is increasingly limited by laws that control application of toxic substances, the innovative process of wood modification works with non-toxic chemicals, preferring types of native origin (Saxe et al. 2011). For the present investigation, the impregnation of poplar wood with following substances was carried out: process water residues from heat treated wood (HT) and hydrothermal carbonisation of biomass residues (HTC) as well as bio-pyrolysis-oils (BO) and methanol-water extracts from Robinia heartwood (RHwE), (Schwager & Lange 1998, Ermeydan et al. 2012, Gierlinger et al. 2003, Grabner et al. 2005).

Results: Based on first modification treatments with non-biocide, but native substances, first results of property improvements of treated wood, mainly focussing on poplar, will be shown: Weight percent gain (WPG) of wood impregnated by agents was about 4-7% in case of RHwE, 4-16% in case of HT and HTC and 64% in case of BO, but the remaining weight percent gain (WPR) after leaching was only acceptable in case of BO (about 60% of impregnated fraction) and RHwE (74-77%), whereas in case of HT and HTC most components were leached (Fig. 1, Table 1). Nevertheless, the improvement of equilibrium moisture content (emc) and mass loss (ML) without (u) and with leaching (l) with water was visible in all treatments. Obviously only small, but very functional and strongly fixed parts of impregnated agents are needed to enhance wood properties. Especially property improvement by HT- and BO- treatment and the high amount of fixed RHwE show promising results.

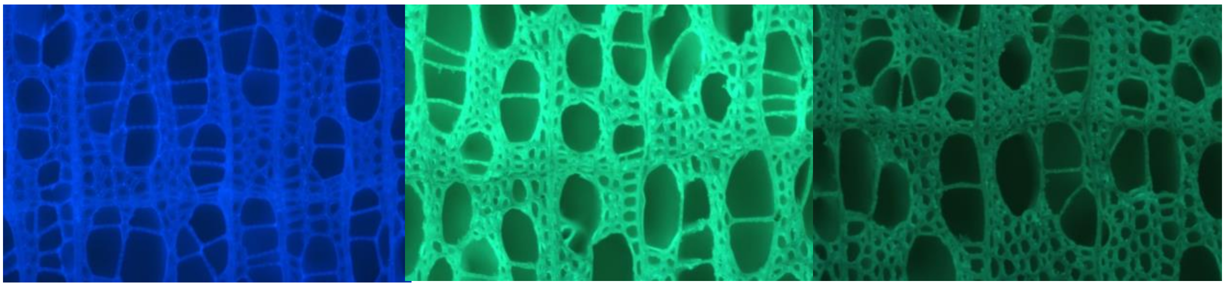

Figure 1: UV-light induced shining in poplar wood: left: Reference, no impregnation (→ no green, but blue); mid: after Robinia extract impregnation (intensive green shining); right: after leaching (low green coloured)

Table 1: Modified properties (legend s. text) in poplar wood without (Reference) as well as after impregnation with process water residues using heat treatment (HT, 180 and 200 °C) or hydrothermal-carbonisation process water using sawmill (sawm.) or miscanthus (misc.) residues, pyrolysis-bio-oil - water mixture 1:1(BO 50%), and Robinia heartwood extracts (RHwE, methanol-water 1:1), using 472, 315 or 158 mg ml^{-1}

Treatment	**WPG (%)**	**WPR (%)**	**emc (%)**	**ML_u (%)**	**ML_l [%]**
Reference	0	0	12	40-50	-
HT 180°C	4.4	-0.2	9.7	15	10
HT 200°C	8.3	0.7	7.9	4	7
HTC sawm.	14	0.8	9.6	22	26
HTC misc.	16	0.8	8.7	10	25
BO 50%	64	38	5.5	13*	1*
RHwE_472	6.5	4.8	-	)	
RHwE_315	4.2	3.1	-	) 13*	
RHwE_158	3.5	2.7	-	)	

**results only available for beech: mass loss (ML) for native beech: 30-44%*

<u>Outlook</u>: First results of property improvement of poplar due to wood modification with native agents show promising results, but fixation and effectiveness need more enhancement.

REFERENCES

ERMEYDAN, M., CABANE, E., MASIC, A., KOETZ, J., BURGERT, I. (2012) Flavonoid insertion into cell walls improved wood properties. Applied Material Interfaces 4: 5782–5789

GIERLINGER, N., JAQUES, D., SCHWANNINGER, M., WIMMER, R., HINTERSTOISSER, B., PAQUES, L. E. (2003) Rapid prediction of natural durability of larch heartwood using Fourier transform near-infrared spectroscopy. Canadian Journal of Forest Research 33: 1727–1736

GRABNER, M., MÜLLER, U., GIERLINGER, N., WIMMER, R. (2005) Effects of Heartwood Extractives on mechanical properties of Larch. IAWA Journal 26: 211–220

SAXE, F., SINGH, A., EDER, M., SINGH, T., BURGERT, I. (2011) Micromechanical and structural characterization of chitosan impregnated Radiata pine (Pinus radiata) wood. Novel Materials from wood or cellulose; IAWA International Conference 31st August – 2nd September 2011

SCHWAGER, C., LANGE, W. (1998) Biologischer Holzschutz. Schriftenreihe Nachwachsende Rohstoffe 11, 727 p.

Curly birch – a peculiarity in the Finnish forests

J. Rikala[1], M. Sipi[2]

[1] Dept. of Forest Sciences, P.O.Box 27, FI-00014 Helsinki, Finland, juha.rikala@helsinki.fi

[2] Dept. of Forest Sciences, P.O.Box 27, FI-00014 Helsinki, Finland, marketta.sipi@helsinki.fi

Keywords: curly birch, wood structure, properties, utilisation

ABSTRACT

Curly birch (*Betula pendula* var. *carelica*) – also known as Karelian birch or visa birch – is a genetic variety of the silver birch. Nowadays curly birch grows naturally in southern parts of Finland, Sweden and Autonomous Republic of Karelia (Russia), in the Baltic countries and Belarus, and sporadically in the eastern parts of Central Europe (PAGAN AND PAGANOVÁ 1994).

Curly birch does not form stands if not cultivated, but is found as clusters of individual trees – often in open cultural landscapes. Appearance of curly birch trees and wood is exceptional. The surface of trunks is knobby-like and uneven. The cross-section of a trunk reveals the wood structure: curly-grained wood with brown stripes or dots consisting of bark that has remained within the wood. There are several types of curled grain of which protuberance curl is the most valuable (HAGQVIST AND MIKKOLA 2008). Identification of curly birch is not always simple due to its various forms. “A visa flower” in the cross-section is one of the most typical characteristics (Fig. 1).

Figure 1: Cross-section of a curly birch trunk (Photo: Juha Rikala)

Two thirds of curly birch used today in Finland originates from natural forests and one third from cultivations. Curly birch is often used as veneers for decorative purposes (Fig. 2). A minor share is utilised as solid wood in ornaments and utensils, e.g., in knife handles. Curly birch is an exception in wood trade since it is sold as weight basis of fresh wood (kg). The value of the best grades may be even 4000–5000 €/m^3 (HAGQVIST AND MIKKOLA 2008).

Figure 2: Curly birch veneer in a table surface (Photo: Juha Rikala)

Key questions in curly birch utilisation are to grow high quality trees and on the other hand to sort out curly birch from normal silver birch trunks. A method based on ultrasound has proved to be promising in the separation (SALMI ET AL. 2007).

The popularity and use of curly birch wood has changed over time. In the 18th and 19th century curly birch was mostly utilised in practical tools and furniture, but nowadays more often in business gifts (KOSONEN 2004). Anyway, rarity and intricate beauty of curly birch wood seem to fascinate carpenters regardless of the trends.

REFERENCES

HAGQVIST, R., MIKKOLA, A. (2008) Visakoivun kasvatus ja käyttö (Management and use of curly birch). Karisto Oy, Hämeenlinna. (in Finnish)

KOSONEN, M. (ed.) (2004) Visakoivu – Curly birch. Metsälehti Kustannus.

PAGAN, J., PAGANOVÁ, V. (1994). Breza biela svalcovitá (*Betula alba* L. var. *carelica* Merk.) na Slovensku. Summary: Curly birch in Slovakia. *Vedecké a pedagogické aktuality* 10/1994: 1-75. Vydala Technická univerzita vo Zvolene v Edičnom stredisku.

SALMI, A., HINTIKKA, T., FORSMAN, P., KARPPINEN, T., HAEGGSTRÖM, E. (2007). Computerized ultrasound differentiating of curly birch from silver birch. Journal of Applied Physics, 101(2), 1376-1382.

SESSION VI
INDUSTRIAL APPLICATIONS

Simulation of continuous drying process including different technologies

B. Hüttler[1], A. Teischinger[2], M. Gronalt[3]

[1,3] Institute of Production and Logistics, University of Natural Ressources And Life Sciences, Feistmantelstr. 4, 1180 Vienna, benno.huettler@boku.ac.at, manfred.gronalt@boku.ac.at

[2] Institute of Wood Science and Technology, University of Natural Ressources And Life Sciences Vienna, Konrad Lorenz-Str. 24, 3430 Tulln an der Donau, alfred.teischinger@boku.ac.at

Keywords: simulation, discrete-event simulation, continuous drying process

ABSTRACT

Various drying methods and technologies are investigated according to their gradients during the drying process. This data is used to derive an optimal moisture contentment related sequence of technologies minimizing drying time. Based on this, a hypothetical sequential continuous four stage artificial drying plant is simulated. A discrete event simulation model is presented to determine the theoretical potential of a multi-method continuous timber drying process in terms of time, capacity and variance of board moisture content. A scenario analysis is carried out to determine the performance and potential of particular plant layouts. Based on a material flow capacities of drying facilities and queues are estimated considering initial moisture content distribution, required utilization rates and maximum percentages of process repeating boards and of course defined final moisture content deviation threshold. Drying gradient curves are results of test series, performed by the Institute of Wood Science and Technology (see TEISCHINGER ET AL. 2013). Manipulation times for transport and technology changes are neglected. Finally potential extensions of the model and further challenges for future research using discrete event simulation are presented.

In order to replace conventional batch drying by a continuous process, the underlying initial moisture content deviation was investigated on a sample size of 2636 boards of spruce with a dimension of 20x4cm provided for drying and is depicted in Fig.1. A study on nine different drying settings using five different technologies (Infrared [IR], High temperature [HT], Jet field [DII], Convection [IP], High-frequency vacuum [HfV]) where carried out to determine reference gradient curves by fitting strict monotonic decreasing composite functions (linear and 3rd degree polynomial) (see Fig. 1). These curves are used in a simulation model to determine time dependent moisture decrement, assuming homogeneous board behaviour. In addition, an optimal sequence of technologies was determined for minimizing drying time (see Table 1).

Table 1: Time optimized drying technology sequence

Stage	**Technology**	**Application range [% rel. MC]** from	to
1	Infrared (IR)	200	55,17
2	Jet field (DII)	55,17%	35,81
3	Infrared (IR)	35,81%	22,45
4	High temperature (HT-120)	22,45%	target level

Based on this sequence a hypothetical continuous drying facility is modelled as a sequential 4 stage process with moisture dependent entry of product. Each stage can be simulated with any

number of independent parallel lanes characterized by different (linear distributed) drying time, modelled as conveyors with different speed. Boards are classified to stages and lanes according to their initial and advanced calculated moisture content. Stage dependent tolerance acceptance criteria of (+5%, +4%, +3% and +2%) from stage 1 to 4 avoids frequent drying beyond target moisture. Boards are classified to lanes according to an even distribution of the acceptance range per stage. Each lane is modelled with a previous queue. Lanes drying time or speed is set to the optimal drying time according to lanes mean acceptance moisture content in respect to target moisture content of stage. The model is built as a discrete event model with steady-state behaviour. Collected result data of interest are the return rate per stage and the maximum number of boards per queue and per lane.
The following scenario analysis is based on a product flow of 100 boards per hour with a board width of 20 cm and a spacing of 2cm. In a first scenario analysis with relaxed lane lengths the number of lanes per stage is successively increased until the return rate per stage drops below a defined threshold of 10%. This results in a 7-2-2-1 lane configuration per stage. Assuming a parallel construction of lanes per stage, given board width and spacing, the drying tube length can be calculated for different utilization rates identified lanes with bottleneck function per stage and are given in table 2.

Table 2: Estimation of drying tube length

Utilization of critical lane [%]	Sum of stage lengths[m]	Waiting Boards per lane [#]
90	281	1-30
95	266	1-57
99	255	1-100

The drying time (time in system, including waiting times) per board is derived from 6.3 to 14.9 hours with a mean value of 11.98 hours.

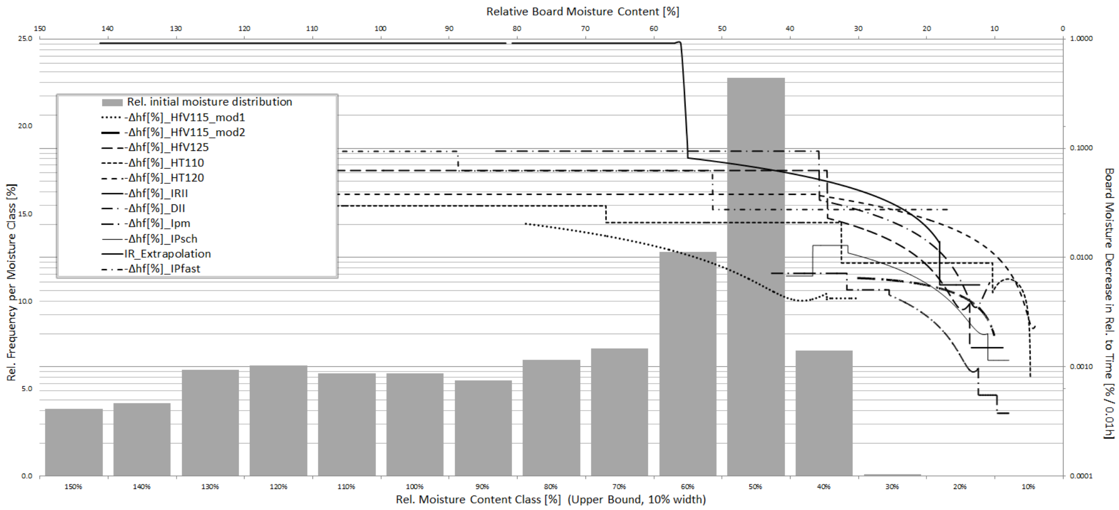

Figure 1: Initial moisture content distribution, fitted drying gradient curves using different technologies

REFERENCES

TEISCHINGER, A., STINGL, R., PLESCHBERGER, H., ZUKAL, M.L. AND HANSMANN, C. (2013) Continuous Lumber Drying by applying a sequence of different drying methods within a single process. *Pro Ligno*. Vol.9 No.4, pp. 650-657.

Technical report of Paulownia Fortunei planted In Iran

T. Tabarsa

Faculty of Wood and Paper Engineering – Gorgan University of Agricultural sciences and Natural Resources(GUSNER) , Gorgan, Golestan, Iran ,tabarsa@gau.ac.ir

Keywords: Iran, Paulownia , plantation, wood yield , grow rate, composite panels

ABSTRACT

Paulownia Fortunei has been imported from china to Iran and grown in North of Iran educational forest of GUSNER in 1995. Many studies have been conducted on it.Data presented below has been obtained during many research which has been conducted during last 19 years. All results support plantation of Paulownia In Iran.

Summary of conducted studies

Growth rate of paulownia at age 14 was investigated. Paulownia fortunei height at age fourteen in North of Iran (Gorgan) reached up to 21.66 [meter] and its diameter reached up to 0.41 [meter]. The most growth rate 80 [millimeter] obtained at age three. Wood production yield in three different plantation patterns are shown in Table 1.

Table 1. Volumetric growth at different age [m³]

Age (year)								Plantation
7	8	9	10	11	12	13	14	Pattern
0.42	0.52	0.63	0.75	0.87	0.98	1.09	1.20	5x6 m
0.68	0.96	1.01	1.13	1.21	1.28	1.32	1.34	6x8 m
0.61	0.75	0.89	1.03	1.16	1.31	1.46	1.59	7x7 m

Wood production per 10000 [m^2] from 277 trees was 345 m^3 (Saeidi and Azadfar 2010).
Physical and mechanical properties of Paulownia Fortunei grown in Gorgan/Iran is illustrated in table 2. Strength to density ratio of Paulownia Fortunei grown in Iran is 159.32 while that of Balsa is 122.25 MPa. (Khazaeian et al. 2009).

Table 2. physical and mechanical properties of Paulownia Fortunei grown in Iran

Density [gr/m^3]	MOR [MPa]	MOE [MPa]	Compression [MPa]
0.26	41.2	3896.30	21.93

Table 3. Fibre dimension of Paulownia Fortuneii grown in Iran (Afra and Hoseini 1995)

Dimension [µm]	Annual ring							
	1	2	3	4	5	6	7	8
Fibre length	800	895	920	948	987	1003	1097	1113
Fibre diameter	31.000	30.850	31.381	31.273	32.126	34.523	31.490	33.183
Cell wall thick.	4.140	4.383	5.810	4.628	5.651	6.015	5.893	5.983

Table 4.Chemical component of Paulownia Fortunei grown in Iran [%] (Afra and Hoseini 1995)

Lignin	Cellulose	hemicellulose	Extractives
29.77	46.20	24.66	6.94

Table 5. Thickness swelling (TS) of treated and control (untreated) Paulownia Fortunei

specimen	Properties				
	Density [gr/m^3]	**Longitudinal TS [%]**	**Radial TS [%]**	**Tangential TS [%]**	**Volumetric [5]**
Control	0.22	0.28	2.79	5.38	8.59
Treated	0.57	0.18	1.75	3.57	5.56

Paulownia Fortunei is a light wood which would improve properties of product in particleboard industry Table 6. (Tabarsa et al. 2010) and Table 7. (Norbakhsh et al. 2009).

Table 6. Properties of PB made of Eucalyptus and Eucalyptus plus Paulownia

PB made of:	Properties		
	MOR [MPa]	**IB [Ma]**	**TS [%]**
Eucalyptus	5.96	0.04	53
Eucalyptus+Paulownia	12.21	0.18	16.42

Table 7. properties of PB made of mixture of Paulownia and industrial particles

Percentage of Paulownia in Mixture	Properties			
	MOR [MPa]	**MOE [MPa]**	**IB [MPa]**	**TS [%]**
100	25.25	2392	0.91	8.59
75	21.90	2065	1.09	8.60
50	18.62	1789	1.28	10.99
25	15.63	1524	1.16	14.97

During densification paulownia react like a spring because its cell walls are thin and when amount of compression is low most of deformation return to the original level. Blocks of Paulownia Fortunei grown in Iran/Gorgan were compressed at different temperatures (130 ^oC, 140^oC and 160^oC up to 16%, 33% and 50% compression. Results are shown in Table 8.

Table 8. Densification characteristics of Paulownia Fortunei grown in Iran/Gorgan

Compression %	**SP [%]**	**Comp. set [%]**	**MOE [MPa]**	**MOR [MPa]**	**Shock [N/m]**
16	12	8	4500	55	15
33	19	22	5100	72	15
50	35	33	6000	81	20

REFERENCES

Saeidi , Z and Azadfar, D. (2010) Effect plantation pattern on growth properties of paulownia. *Journal of Iran forest*, Association of Iranian Forest, vol.2 no.2.

Khazaeian, A. Yagmaei, F. and tabarsa, T. (2009) Study of bending and compression strength of apulownia planted in Iran. *J. of wood and forest science and technology* vol.16 N0 3 : 35-88.3

Afra, A. Hosseini, S.Z. (1995) Investigation on paulownia fiber dimension and chemicals grown in Gorgan. J. of Iran natural resources vol 58 NO 3

Tabarsa, t. Dosthoseini, K. and farsi, M. (2010) . Investigation on improving effect of paulownia in manufacturing particleboard from Eucalyptus. *Journal of Forest and wood products* vol 63 No 1 : 23-30

Edalat, H. R. Tabarsa, T. Raeisi, M. (2008) Densification of paulownia using hot-press. *Iranian journal of wood and paper science research* vol 23 No. 2.

Industrial applications for poplars based on selection and breeding using traits related to both optimized properties for material and energetic usage

J. Van Acker[1], N. Defoirdt[2], J. Van den Bulcke[3], L. De Boever[4], D. Vansteenkiste[5]

[1] Ghent University (UGent), Laboratory of Wood Technology (Woodlab), Coupure links 653, 9000 Ghent, Belgium, e-mail: Joris.VanAcker@UGent.be

[2] e-mail: Nele.Defoirdt@UGent.be

[3] e-mail: Jan.VandenBulcke@UGent.be

[4] currently at Belgian Technical Centre of Wood transformation and Furniture, e-mail: Lieven.DeBoever@UGent.be and Lieven.DeBoever@ctib-tchn.be

[5] currently Project Manager at the Green Earth Fund and founder of iYi - Biomass Business Developments SRL, e-mail: DriesC.Vansteenkiste@gmail.com and Dries.Vansteenkiste@Green-EarthFund.com

Keywords: Poplar, engineered wood products, selection, energy use

ABSTRACT

The selection and breeding of poplar and willow clones is the basis for the future forestry wood chain of poplar / willow. It remains probable that an integrated wood sector will provide both quality material products and allow for bio-energy as part of our socio-economic system. It is nevertheless important to question to what level we can still combine wood quality and bulk production. Based on the changing policy related to this it might still be good to focus as much as possible on both as the outcome of selection and breeding of poplar clones only results in having several options in the (near) future. Both specific end uses and multipurpose applications can be envisaged. The new Belgian poplar clones provides opportunities to do so. Additionally we will need to use better high throughput methodology to support selection and breeding allowing for both forestry and agriculture linked biomass production of timber – wood – lignocellulosics. This demand for more lignocellulosic material in general creates a renewed interest in poplar plantations but we should work on poplar/willow forestry wood chain strategies. These should however not necessarily comply with all the 'fashionable' words like sustainability, climate change, renewable energy and C-sequestration.

In Fig. 1 some poplar hybrid clones are presented having a different growth rate (data from the EU project Noveltree 2008-2012 FP7-211868). Values of ovendry density and green moisture content reveal considerable option to select. Such parameters can be complemented with other traits relevant for either material usage as construction timber or engineered wood products or energy conversion either using the biochemical or thermochemical conversions route to produce biofuels, chemicals or direct energy production.

Both international platforms such as the International Poplar Commission (IPC, ISEBRANDS AND RICHARDSON 2014) and several teams work on populicultural systems, product innovation and increased potential usage of poplar wood (CASTRO AND ZANUTTINI 2004, DE BOEVER *ET AL.* 2011, VERLINDEN *ET AL.* 2013).

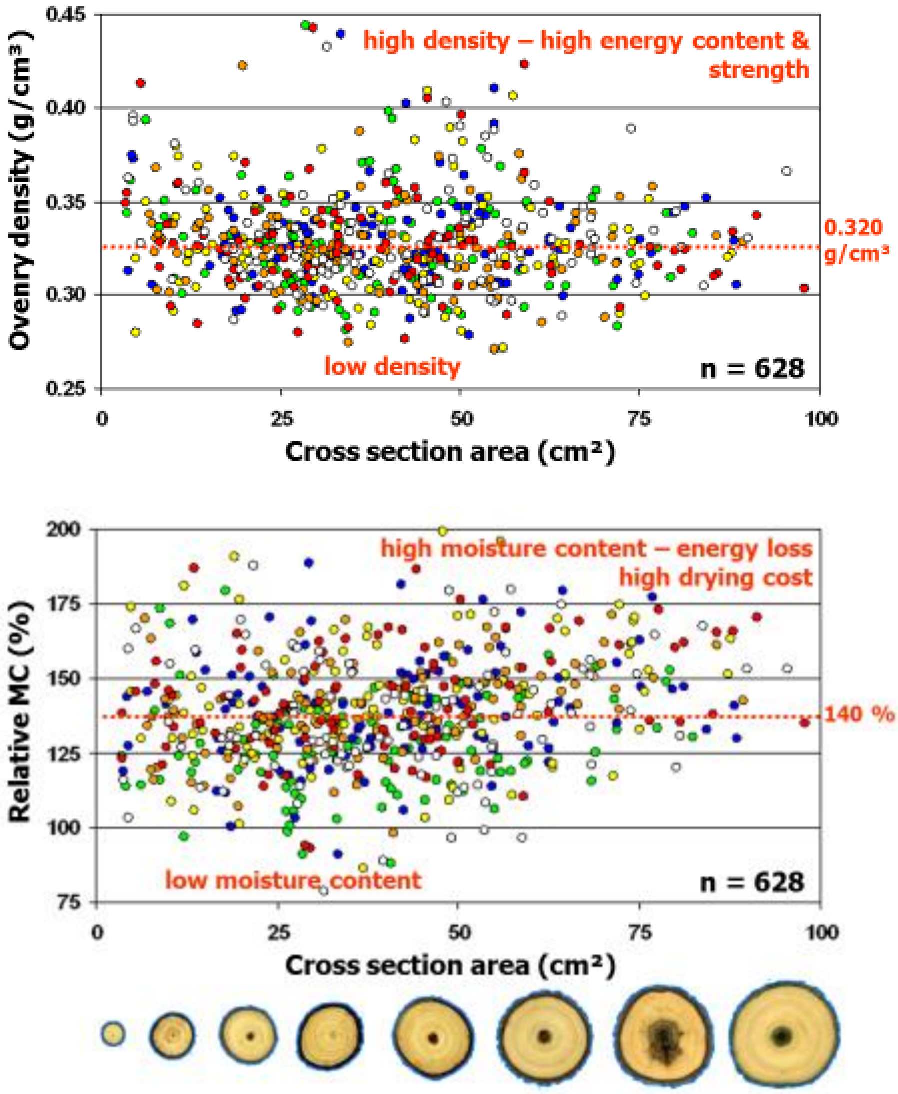

***Figure 1:** Slow up to fast growing poplar hybrids and their ovendry density (top) and the related green moisture content (bottom)*

REFERENCES

ISEBRANDS, J.G. AND RICHARDSON, J. (2014) Poplars and willows: trees for society and the environment. Published jointly by CAB International and FAO, Rome. 634p.

CASTRO, G. AND ZANUTTINI, R. (2004) Multilaminar wood: Manufacturing process and main physical-mechanical properties. *Forest Products Journal* **54** (2): 61-67.

DE BOEVER, L., VANSTEENKISTE, D., STEVENS, M., VAN ACKER, J. (2011) Kiln drying of poplar wood at low temperature: beam distortions in relation to wood density, tension wood occurrence and moisture distribution. *Wood research* **56** (2): 245-256

VERLINDEN, M.S., BROECKX, L.S., VAN DEN BULCKE, J., VAN ACKER, J., CEULEMANS, R. (2013) Comparative study of biomass determinants of 12 poplar (*Populus*) genotypes in a high-density short-rotation culture. *Forest Ecology and Management* **307**: 101-111

Experience in hardwood utilisation for solid biofuels with focus on the reduction of ash content

M. Weigl[1], A. Haider[1], W. Pichler[1], M. Steiner[1], M. Pain[1], R. Götzl[1], J. Schlapschy[2], K. Jörg[2]

[1]Holzforschung Austria – Department of Bioenergy and chemical Analytics, Franz Grill Str. 7 1030 Vienna, Austria, m.weigl@holzforschung.at

[2]OFI Technologie & Innovation GmbH, Franz Grill Str. 5, 1030 Vienna, Austria

Keywords: wood pellets, ash content, solid biofuel, certification, material quality

ABSTRACT

Background: Energetic use of wood is nowadays widely understood as a good alternative to fossil fuels. Stringency of resources and raw material pricing however stresses relations between different industries, focusing on wood utilisation such as pulp and paper, solid wood, wood based panels or bioenergy. All of these currently focus on raw material substitution leading to increased interest on hardwood for applications nowadays typically using softwoods. Taking pellets as an example, originally residues coming from sawing processes were dedicated as a raw material. Hence, focus is typically on softwoods. However, due to geographical availability, impact of climate change on forest growth and other reasons, several pellet producers decided to focus on hardwood species. For example, European beech (*Fagus sylvatica*) is of major interest due to good availability in different central, eastern and southern European countries. Processing such species typically alters production processes, compared to well establish processes focusing on softwood pelletising. Hardwood as raw material for pelletizing is mostly round wood which has to be chipped and grinded before the pelletizing process. Thus, storage and handling of the raw material show impact on material contamination. Trunk shape and bark type influence debarking efficiency in a negative way. Also, energy consumption while disintegration and compaction is strongly affected. Some of these problems might be overcome by altered production path ways.

Focus: Material contamination caused by the factors stated above result usually in higher ash contents of the pellets produced. The current widely utilised certification scheme ENplus specifies 2 quality classes for wood pellets that today are represented in the market (Table 1). The 3rd quality class EN B has no relevance in the market and is therefore neglected in this study. All the quality classes are based on the European standard for wood pellets EN 14961-2. Considering hardwood pellets the ash deformation temperature which is an important parameter for the smooth operation of small scale heating appliances usually meets the requirements of A1 quality. This parameter is influenced by undesired ash composition.

Table 1: Quality classes for wood pellets ENplus

Quality class	ash 550°C [w%]	Ash deformation temperature [°C]
ENplus A1	≤ 0,7	≥ 1200
ENplus A2	≤ 1,5	≥ 1100

However, reaching the high graded A1 quality level constantly currently seems almost impossible with hardwoods because the threshold value for ash content of the pellets usually is not met. Major reasons are material contamination in the supply chain and an assumed

generally higher ash content of hard woods. Figure 1 gives a comparison of the ash content (left) and the ash melting properties (right) of typical pellets produced from spruce and beech wood respectively. Beech wood pellets clearly show increased ash contents and undesirable ash melting conditions. The rather high ash flow temperature of beech must be seen in the context of higher inorganic contamination, being rather a weakness than a potential.

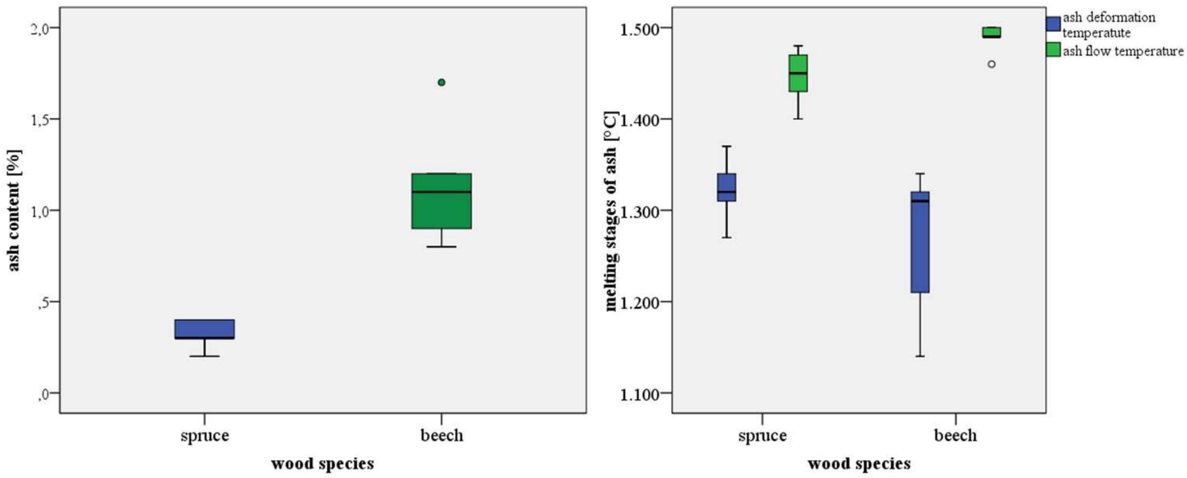

Figure 1: Comparison of ash content and ash melting properties of spruce and beech wood (n=5 each)

This problem is tightened because of the new ISO 17225-2 standard which will replace EN14961-2 in 2014. In this standard the requirement for ash content of A2 quality is reduced to ≤ 1,2 %. It's conceivable that this new threshold value will be implemented soon also in a future version of the ENplus Handbook.
Aim of the study is 1) to characterize typical ash contents in hardwoods form different regions in Europe (at least Central Europe, Eastern Europe, Balkan peninsula) with a focus on European beech following the principal of thermogravimetric analysis in a multi-sample mode (TGA701, Leco Instrumente GmbH). Sapwood, mature wood, facultative heartwood, and bark are tested. Based on this data conclusions can be made if A1 quality is possible with hardwood at all. In stage 2) laboratory experiments aiming on the reduction of ash content are performed by means of washing. Mineral components originating a) from impurities added in the supply chain and b) from the composition of the wood itself shall be removed. Stage 3) covers pelletizing test performed with different blends of raw material to produce constant A1 quality with a hard wood content as high as possible. Throughout the whole experiment, all relevant process parameters such as material flow or energy consumption are recorded, and pellet quality is accessed.
Target outcome of the study is to provide information for existing and potential future producers of hardwood pellets regarding their options to produce A1 quality in order to fulfil market needs.

REFERENCES

European Pellet Council: Handbook for the Certification of Wood Pellets for Heating Purposees. Version 2.0 (2013)

ISO 17225-2:2014 05 01 Solid biofuels - Fuel specifications and classes - Part 2: Graded wood pellets

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WKO

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