IPC Working Party on Harvesting and Utilization of Poplar and Willow Wood
2nd Conference on Engineered Wood Products based on Poplar/willow Wood
León, Spain, September 8th-10th 2016

Poplar Wood Related Research in Hungary

Róbert Németh[1], Sándor Fehér[1], József Ábrahám[1], Miklós Bak[1], Norbert Horváth[1], Szabolcs Komán[1], Péter Szeles[1]

[1] University of West Hungary, Institute of Wood Science, Bajcsy-Zsilinszky u. 4., H-9400 Sopron, Hungary [emails: nemeth.robert@nyme.hu; feher.sandor@nyme.hu; abraham.jozsef@nyme.hu; bak.miklos@nyme.hu; horvath.norbert@nyme.hu; koman.szabolcs@nyme.hu; szeles.peter]

Keywords: energetic use; glulam structures; oil-heat-treatment; poplar wood; thermo-mechanical treatment

ABSTRACT

The aim of the poplar-related research work in Hungary is mainly about enhancing the technical performance of the poplar (*Populus x euramericana*) wood material. Poplar plantations with high growing rates deliver valuable raw material for different sectors in the wood industry (plywood, WPC's, construction wood, and even solid wood for different applications). However, there are some disadvantageous properties like low mechanical strength, low surface hardness, and nevertheless the unexciting texture and appearance. The last mentioned properties restrict the use of poplar in many fields of applications, e.g. the furniture and the flooring industry. By upgrading the unfavourable properties of poplar wood new and very promising applications could be defined. The energetic use of poplar wood is a common way for poplar utilization, but with optimization of the species selection having regard to the type of the production site it can be more efficient. Several wood modification methods like thermal treatments and thermo-mechanical treatments are a good opportunity to increase aesthetical and mechanical performance of poplar wood. However, poplar wood is traditionally not used as a material for load bearing elements, according to the mechanical performance of several poplar varieties it is also possible.

INTRODUCTION

Utilization of poplar wood has a long tradition in Hungary, thus it is used in countless utilization fields. There are several reasons for this diversified utilization of poplar wood. On the one hand, several poplar species are indigenous in Hungary, which can have significant differences in the physical and mechanical properties, e.g.: *Populus alba* and *Populus nigra*. On the other hand, there is an intensive work being done in Hungary to breed new varieties (clones) with very different physical and mechanical properties, what ensures the possibility to utilize poplar wood at a large scale of utilization fields. Beside the "traditional" utilization fields of poplar wood like packaging material, crates, pallets, plywood, paper- or cellulose production, nowadays it is used also for furniture production and in the wooden architecture as well. It was used rarely for wooden architecture in the past as well, because of its good mechanical properties related to its density. But it was never a traditional building material, however several poplar species or varieties have mechanical properties close to in the building sector traditionally used Norway spruce. Research fields related to improve its properties are the different wood modification techniques and the production of different glued poplar products like LVL or glulam elements. The use of such techniques and production of such products can widen the utilization fields of poplar wood. But of course not to forget about the well-known potential in the use of poplar varieties in the energy production as renewable raw materials. One of the most important source among the renewable energy sources, especially in Hungary, is the biomass. Researches has clearly shown that different biomasses, agricultural-, sylvicultural residues and wastes have and will have a key role in the renewal of the energy production worldwide. Despite, that Hungary has a great agricultural potential, the most important source of the biomass are the energy plantations. For energy plantations fast growing species can be taken into consideration, mainly poplar, willow or robinia. In accordance with these information, the number of both the national and international researches related to poplar wood is showing an increasing tendency. This is reflected as well in the research activity of the Institute of Wood Science at the University of West Hungary, as our research is much diversified in this topic. The range of our poplar wood related research covers the traditional wood testing, different wood modification techniques, energetic use, or utilization as a building material in the form of a glulam element.

ENERGETIC CHARACTERIZATION AND USE

The role of biologically renewable resources is continuously increasing in the energy sector. Wood plantations belong to this group, and Kyoto convention also recognized them as a tool for decreasing the emissions of greenhouse gases. Especially the fast growing species, like poplar, willow or robinia can be considered for energetic plantations. The reason for this is the high production rate of dry matter and the high sprouting capability. These plantations with short harvesting cycles can produce a large amount of biomass as a renewable energy source. To maximize the occupancy of the plantation fields, species and variety have to be chosen fitting the best for the given conditions. By choosing the variety several factors need to be considered. One of our latest research was related to the calorific value of poplar energy plantations on production sites having different quality. The energy yield of a plantation based on the calorific value is an important factor for their characterization.
According to the different characters, three production sites have been chosen in Hungary (Celldömölk, Sárvár, Borjád) (Figure 1.). The investigated varieties were 2 years old ’I-214’,’Kopecky’ and a new variety bred by ERTI (Forest Research Institute). Samples were taken from 3 different heights of trees – bottom, middle and upper side. Excepting the upper side, the calorific value was determined for the xylem and the bark as well.

Figure 1: Experimental plantations of 'I-214' poplar with different production site conditions (Borjád, Celldömölk, Sárvár)

It was stated that there was no significant differnce by weight between the calorific values of the investigated varieties. However, there was a huge difference by volume (Figure 2.). The best calorific value by volume was found for 'Kopecky', followed by 'ERTI' and 'I-214'. No significant differences could be found between the calorific values (by volume) of the different production sites. But if we consider the different yields of the sites and count the calorific value per hectars according to that, huge differences can be found. It can result in two times higher energy yields per hectars, if the species and variety is chosen properly, considering the conditions of the site (Figure 3.).

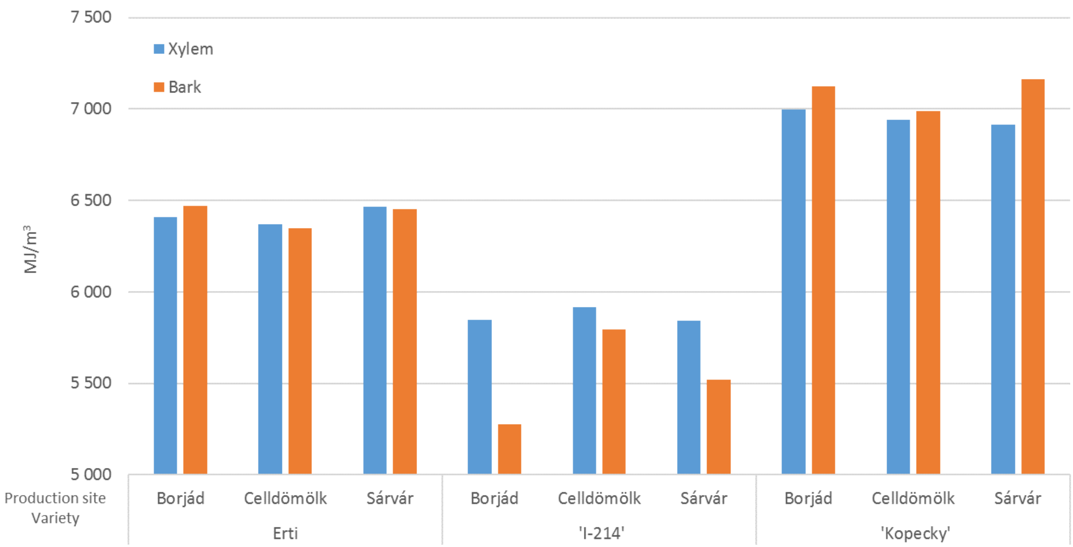

Figure 2: Calorific value of the different poplar varieties at different production sites

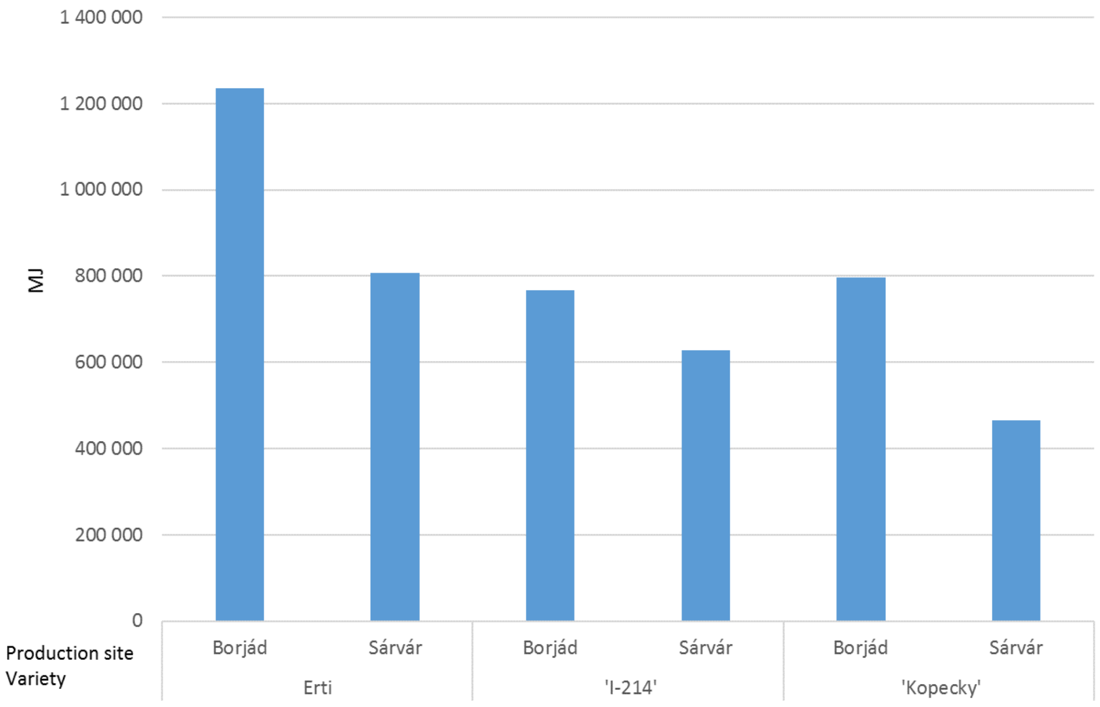

Figure 3: Calorific value of the different poplar varieties per hectare

THERMOMECHANICAL TREATMENT OF PANNONIA POPLAR (*POPULUS X EURAMERICANA* CV. ’PANNONIA’)

In order to surmount the obstacles, we focussed our research work to enhance the relevant physical, mechanical and esthetical properties of poplar wood. The specific aim was to establish the scientific background for a thermo-mechanical modification method. The process should enhance the surface hardness, the strength and the appearance of this low density wood with thin fibre walls.

Poplar laths were densified in hot press across the grain at 3 different temperatures. 160°C, 180°C and 200°C. Three different starting thicknesses (25.0mm, 28.5mm and 33.3mm) were used. The final thickness of the laths was set to 20mm for all laths. Thus the grade of the densification was 20%, 30% and 40%. After the densification under heat, the wood material was kept for 10, 20 and 30 minutes in the hot press at the corresponding temperature. After the treatment the change in different material properties were studied. The investigated properties were: the colour change, moisture related shrinking and swelling, surface hardness, MOR and the grade of densification across the thickness.

Studying the total colour change, values over 3 can be found by all treatments. Thus the colour change is visible even at the lowest duration, temperature and densification grade to the naked eye (Figure 4.). As for all the three investigated colour coordinates (L*, a*, b*) showed similar changes, the ΔE* is influenced particularly by the temperature (highest changes at 200°C, 30% and 30 min.). The longer duration of the pressing treatment did not result in significantly higher total colour changes at 160°C and 180°C. The densification grade did not influence the colour change.

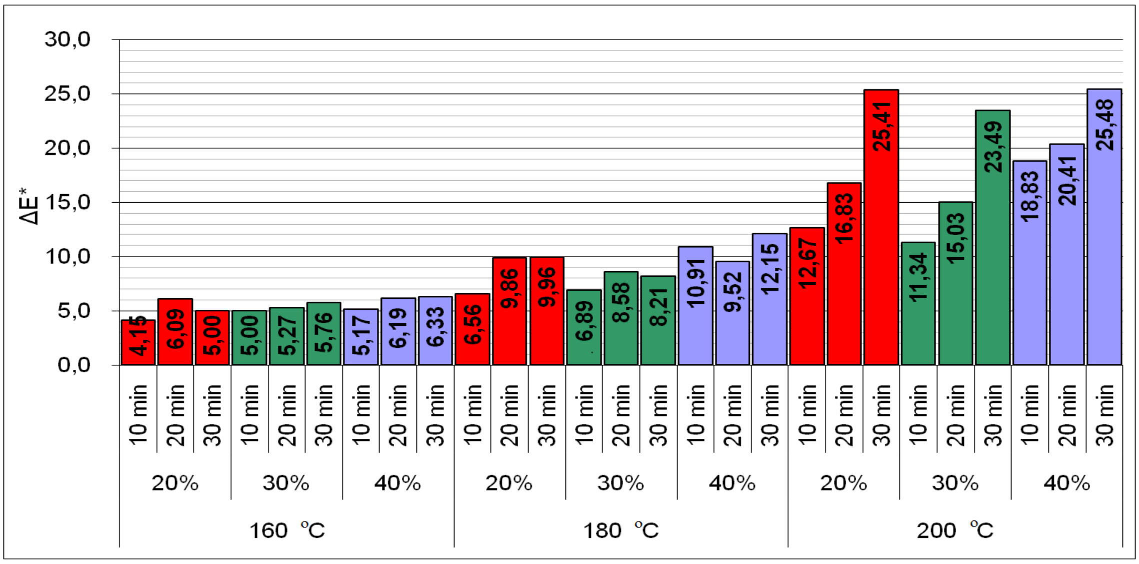

*Figure 4: The effect of treatment parameters on ΔE**

One of the main targets of this research work was to enhance the surface hardness of poplar wood. The corresponding values for untreated timber were in the range of 8-11 MPa. The relative low values could be increased by the applied thermal densification method up to the range of 15-22 MPa. Figure 5 shows a clear positive effect of the treatment in terms of hardness change. From the results we can conclude that the densification grade is the most prevailing among the treatment parameters.

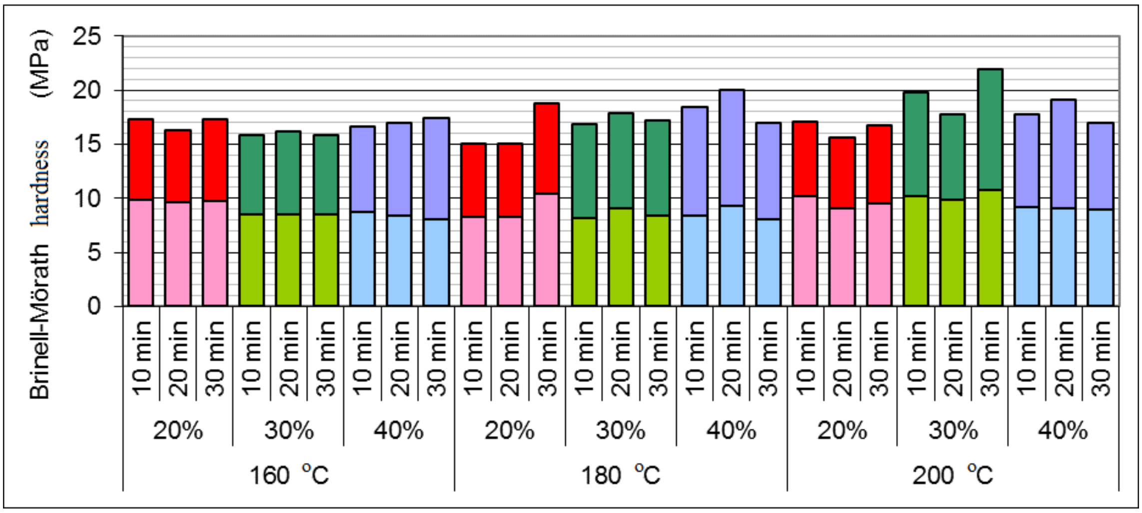

Figure 5: The effect of treatment parameters on the Brinell-Mörath hardness (light column before and dark column after the treatment respectively)

The average MOE of control material amounted to 79,85 MPa. These values could be increased to the range of 87-116 MPa. The treatments enhanced the MOE of the material. No clear influence could be proved for single treatment parameters (temperature, duration and densification grade). It has to be mentioned that the coefficient of variation (20-25% cv) for treated MOR values increased compared to the cv of the controls.

The shrinking ability was determined in three directions: parallel to the grain, across the grain and parallel to the pressing force (thickness), across the grain and perpendicular to the pressing force (width). The shrinking coefficients (treated and control) in thickness and width are shown on Figure 6. No differences could be found for shrinking parallel to the grain and in width, while in thickness considerable increase in shrinkage could be proved. At all investigated temperatures the higher densification grade resulted in higher shrinkage. Because of the relative short treatment time, the thermal treatment modified the surface only, even at the highest value (200°C). Thus no thermal degradation occurred in the inner layers, therefore, no stabilisation effect could be aimed.

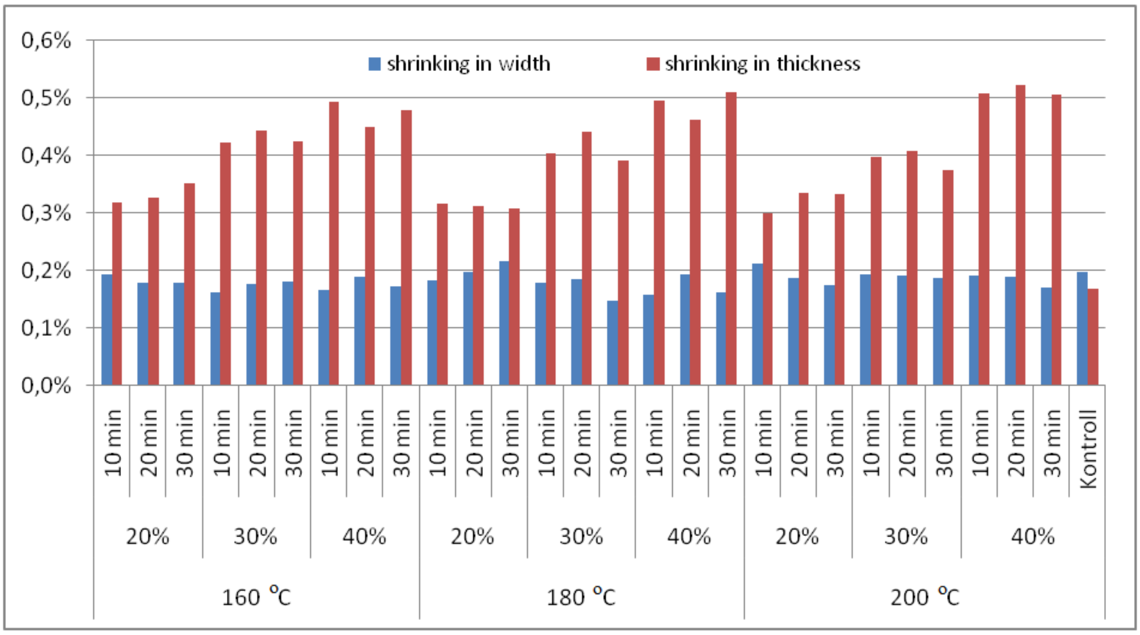

Figure 6: The effect of treatment parameters on the shrinking coefficient in width and in thickness

It was stated that there is a positive correlation between the densification grade and the ovendry density. The final density value is determined by the initial density of the laths.

It should be mentioned that the densification grade is not evenly distributed across the whole thickness. Studying the deformations of the straight lines which were drawn on the side surface of the laths prior to the treatment we can get information concerning the distribution of the densification across the (half)thickness (Figure 7.). Applying the lowest bulk densification grade of 20% the local densification of the upper 1/3 layer amounts to 40%, while the inner parts show rather slow 0-10% local densifications. Applying the moderate densification grade of 30% the local densification of the upper 1/3 layer amounts to 45-50%, the second 1/3 layer shows 30% densification, while the inner part densifies ca. 10-15%. Applying the highest densification grade of 40% the local densification of the upper 1/3 layer amounts to 50-55%, the second 1/3 layer shows ca. 30%-40% densification, while the inner part densifies about 20-25%.

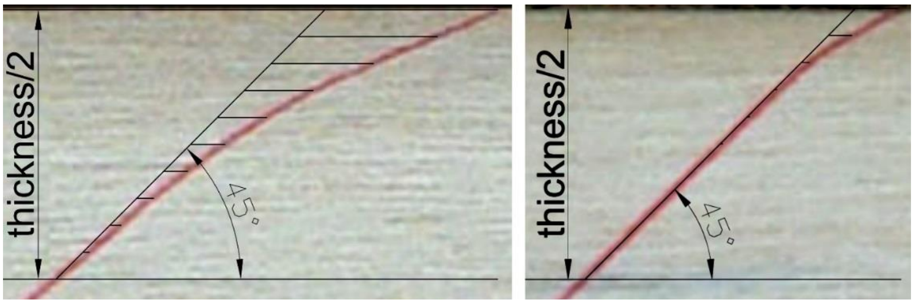

Figure 7: The densification of different layers due to densification values of 40% (left) and 20% (right)

OLEOTHERMIC TREATMENT (OHT) OF POPLAR WOOD

The interest for different heat treatment methods increased continuously during the last decades. The reason for that is the decreasing amount of accessible tropical timber with high value and durability, and of course the increasing demands on environmental friendly, or even chemical free wood preservation from both customer and governmental sides.

The thermal treatment of wood was a research topic long ago, and the processes were permanently optimized in different countries. The first trials were made already in the '20-s, but targeted investigations only began decades later. Since that time 5 different processes have been widely used in Europe. They are: ThermoWood – Finland, Plato wood – The Netherlands, Retification and Perdure – France, and OHT (Menz Holz) Germany. The basic technology parameters are more or less the same in case of all treatment technologies (treatment temperature and time), but there are major differences in the used treatment medium. The type of the medium has essential impact on the final result, thus this is the main difference between the different technologies. Heat treatment in vegetable oils (OHT) is probably the fastest technology, because the treatment time is usually not more than 8 hours, in spite of the 10-20 hour treatment times of other technologies using gases or steam as a treatment medium. (Esteves and Pereira 2009). As a result of heat treatment the utilization fields of less used wood species can be widened. In Hungary these species are mainly plantation grown timbers like robinia (*Robinia pseudoacacia*) and poplar (*Populus × euramericana*). Mainly the utilization of poplar wood is limited only to several fields (energy, pallets, plywood and panel industry), however it is available in large quantities. With the help of heat treatment products with more added value can be produced from this material available in large quantities.

Equilibrium moisture content (EMC) of heat-treated poplar wood decreased significantly, which is strongly correlated with the improvement in dimensional stability. The dimensional stability of heat-treated poplar wood improved significantly (Figure 8.) A reduction in swelling was already noticeable under the mildest treatment (160°C/2h), decreasing 21% in the radial direction and 29% in the tangential direction. The best dimensionally stabilisation was obtained at 200°C with 6 hours of treatment, as expected. This treatment resulted in a 39% decrease in the radial direction and a 46% decrease in the tangential direction. The anti-swelling efficiency in the tangential direction was higher for all treatments. The difference between ASE values in the radial and tangential directions was observed between 7 and 11%, irrespective of the treatment time and temperature. This result shows that although the swelling anisotropy decreases, it will not disappear. The result that the difference between ASE values in the radial and tangential directions is constant by the several schedules shows, that the effect of treatment time is independent from the treatment temperature.

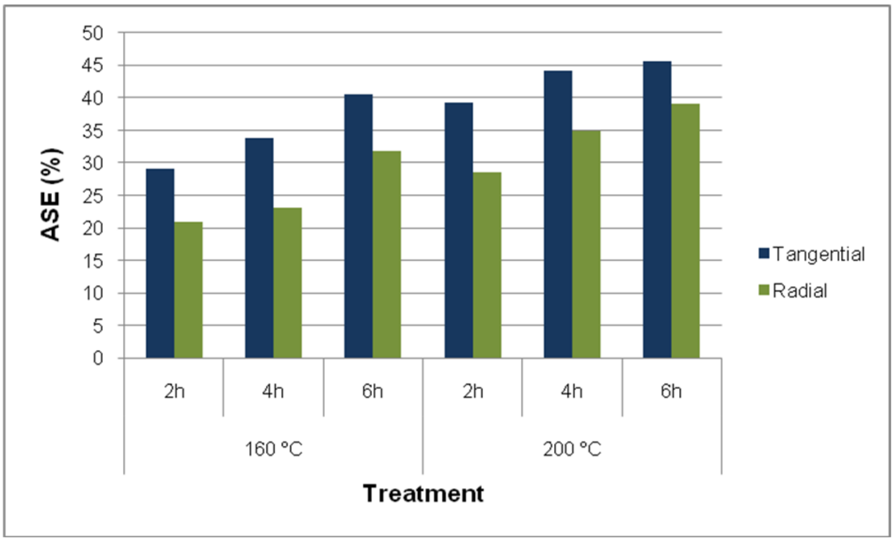

Figure 8: ASE values after OHT in linseed oil (T= 20°C, φ= 65%)

During the service life of a product the surrounding climate is regularly changing, thus the EMC, and therefore the dimensions, are changing too. These changes are usually more or less cyclic and short term. The moisture content of heat-treated specimens was lower at all of the investigated time intervals, compared to the untreated wood. The change in moisture content of oil heat-treated wood was similar to that of the untreated wood, as after 48 hours the moisture content increased only slightly, and all specimens were close to the EMC (Figure 9.). It can be stated that OHT treatment reduces the moisture uptake rate because heat-treated samples adsorb less moisture during the same amount of time than untreated samples. But, considering that saturation occurs during the same time by natural and heat-treated wood, it is revealed that a decrease in the moisture uptake rate in OHT wood is due to the decrease in water storage capacity. However, a decrease in moisture uptake rate is only apparent. By dividing the reduced equilibrium moisture contents (due to OHT treatment) by the momentary moisture contents, no significant differences can be found between untreated and OHT samples. This result shows also that due to chemical changes during heat treatment, moisture uptake into the cell wall and the bounding of water molecules is not blocked, because all samples reached EMC nearly at the same time. The apparent decrease in moisture uptake rate is therefore due to the reduction in the amount of sites, which are able to bound water molecules. Namely, the water bounding capacity decreases, not the water bounding capability. Apart from that, under changing climatic conditions the use of heat-treated wood is preferable. Also, due to this apparent decrease in moisture uptake rate, swelling/shrinking will be smaller in heat-treated wood compared to natural wood for the same time interval.

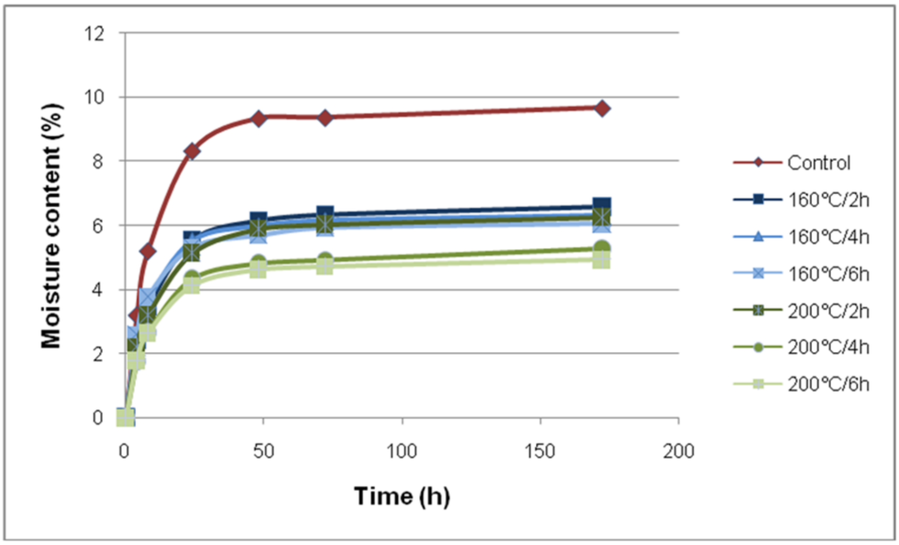

Figure 9: Changes in moisture content of OHT and untreated poplar wood at normal climate (T= 20°C, φ= 65%) as a function of time (Treatment medium: linseed oil)

In general, moisture transport through the untreated samples was significantly higher compared to the heat treated samples in both radial and tangential direction (Figure 10.). As a result of heat treatments, diffusion decreased ~65% in tangential and ~80% in radial direction. As expected, diffusion of untreated material was lower in tangential direction compared to the radial direction. In case of heat treated samples these differences were diminished between the anatomical directions. Namely, in case of OHT samples the diffusion was the same in the different anatomical directions, significant differences could not be established. One reason for getting the wood more water vapour resistant as a result of heat treatment can be the decreasing hygroscopicity and equilibrium moisture content. These phenomena decrease the moisture content difference between the two surfaces of the wood, which are exposed to different climatic conditions (in this case 0% and 65% RH). Thus, the moisture gradient is becoming smaller. On the one hand this slows the moisture diffusion through the wood. On the other hand as a result of de-composition of the sorption sites during heat treatment, the distance between the hydroxyl groups in the cell wall will increase which will slow the diffusion as well. However, the diminishing the differences between the moisture transport rate of radial and tangential direction is an advantage during utilization.

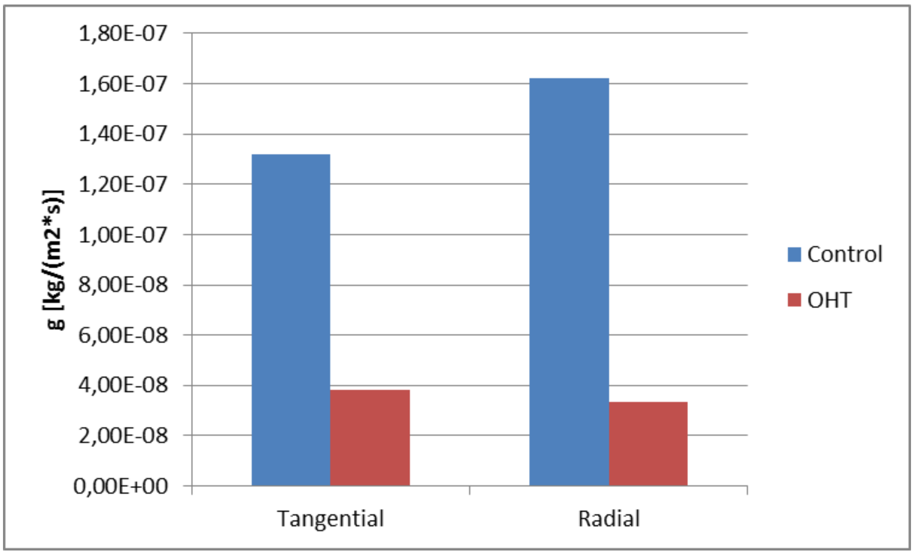

Figure 10: Density of water vapour flow rate for untreated and oil-heat-treated (OHT) wood material in tangential and radial directions

PRODUCTION OF POPLAR-BASED GLUED-LAMINATED ELEMENTS

The focus was set in this research on the poplar clone called I214 (*Populus×euramericana* cv. I 214), which is not only important and widely used in Hungary but in Europe as well. This variety is named also as suitable variety in the European standard EN 14080 which describes the requirements of glued-laminated timbers.

Material properties

Material was provided by the Pilis Forestry Company from the Middle-Hungarian region. Average density at normal climate of the material was 368,3 kg/m^3 with the standard deviation of 20,6 kg/m^3. Equilibrium moisture content at normal climate was 10,6%. Shrinking anisotropy was 1,6, which is suitable for the production of glulam products from the point of view of possible delamination.

Production of prototypes

Straight glued laminated elements were produced from the material. The lamellae dimensions were 20×70 mm. Lamellae were graded by a non-destructive equipment, which was developed at the University of West Hungary. The material was sorted to mechanical classes according to the standard EN 338. After ranking, finger jointing of the lamellae was made to the length of 2000 mm. The glue type used for the production of the glulam elements was a fibre reinforced one component polyurethane glue (Jowat 686.60). The prototypes were made of 5 layers of lamellae. For the external layers lamellae from the mechanical classes C27 and C30 were used, while for the middle layers C22 and C24. Final dimension of the prototypes was 20×70×2000 mm.
Mechanical testing of the prototypes was made with a three-point bending test according to the standard EN 408 (Figure 11.). Results showed that the modulus of elasticity of the prototypes was 11316,22 MPa in average, while bending strength was 45,9 MPa. However, these results are promising, further tests are required in terms of dynamic properties or susceptibility for delamination.

Figure 11: Bending test of a poplar glulam prototype

REFERENCES

Esteves, B., Pereira, H. (2009) Wood modification by heat treatment: A review. *Bioresources*, **4**(1), pp. 370-404.