Chemical-free Wood Preservation – The Effect of Dry Thermal Treatment on Wood Properties with Special Emphasis on Wood Resistance to Fungal Decay

Norbert HORVÁTH * – Károly CSUPOR – Sándor MOLNÁR– Róbert NÉMETH

Department of Wood Sciences, University of West Haungary, Sopron, Hungary

Abstract – Heat treated wood, as a raw material is discovered again and more and more frequently used in the wood industry nowadays. The aim of this treatment is to amend the wood properties without chemicals. The thermally modified wood is discussed as a new material for several applications. The primary aim of the presented study was to promote the production of thermal treated wood in Hungary. In the research the most important wood species with low fugal decay resistance – Turkey oak (*Quercus cerris* L.), beech (*Fagus sylvatica* L.) and Pannonia poplar (*Populus* × *euramericana Pannonia*) - were investigated at the Institute of Wood Sciences of the University of West Hungary in Sopron. This project called "Chemical-free wood preservation" was supported by the Ministry of Economy and Transport and was completed in March 2008. Due to the success of this endeavour, the industrial production of the thermal treated wood was started at the SOKON Ltd. The thermal treatments were carried out under atmospheric conditions. The temperature of the treatments ranged between 180-200°C and was combined with a wide range of durations. The know-how developed within the frame of this research is owned by the members of the consortium formed by the University of West Hungary, SOKON Ltd., and Apostol és Társai Ltd. The most important physical and mechanical properties were analysed using the European Norms (EN). The biological durability tests were carried out in accordance with the EN 113 standard. The test fungi were oak maze gill (*Daedalea quercina)* and Turkey tail (*Coriolus versicolor).* Based on the results, the fungal decay resistance and the dimension stability of wood can be enhanced for the wood species studied. In addition, the heat treatment was found suitable for homogenizing the colours between white and red heartwood of beech and decreased the colour-difference between sapwood and heartwood of Turkey oak. Significant correlation was found between brightness (L*, CIE-Lab) and other tested properties.

Keywords: Wood preservation / Heat treatment / Fungal decay

1. INTRODUCTION

In a narrow sense, under thermal treatment we mean the heat transfer exceeding the usual temperature scope of timber drying, which significantly changes the properties of timber, due to the processes of degradation. The timber modification methods by the means of heat can be considerably different regarding the agent and schedule of treatment. Regarding the heat transferring agent we can mention technologies using liquids, or gas-steam. As liquid heat transferring agents, vegetable oils, like rape-oil, flax oil, etc. can be mentioned. Its industrial use is not remarkable, however we can see case of using it for example at the MENZ HOLZ company. In case of treatments with gas agent, normal atmospheric air, flue gas, inert gas atmosphere and vapour can be mentioned. Spreading of treatments in gas agents is very fast since the appearance of Finnish Thermo Wood in the nineties. This Finnish brand name

* Corresponding author: hnorbert@fmk.nyme.hu, 4. Bajcsy-Zsilinszky street Sopron 9400 Hungary

means a market leader thermally treated wood product from coniferous raw material all over Europe. Due to this, thermal treatment of wood materials re-appeared at the centre of not only the industrial development, but scientific research as well. During the last decade, other countries of Europe followed the Finnish ones on the list of manufacturers and sell thermally treated wood products from broadleaved species under their own brand (Mirako-Thermoholz, PlatoWood, PerdueWood etc.). Among manufacturing technologies, the most widely used are the ones using dry air and superheated steam. Based upon these considerations, domestic research and development work followed this direction.

2. MATERIALS, METHODS AND RESULTS

We performed tests to base the industrial realisation of thermal treatment of timber, with domestic species. The research was supported by the Ministry of Economy and Transport in the framework of „ Chemical-free wood preservation" project. The aim of the project was to clear up the effect of thermal treatment from not only the aspect of the resistance to fungi, but of other properties as well. According to the preliminary tests, the temperature of tests was limited to 200°C and the heat transmitter agent was dry, normal atmospheric air, without blowing steam. The schedules of the treatment are the intellectual property of the consortium formed for the realization of the project, so we are not allowed to publish details about those. The increasing numbers of schedules mentioned (1,2 and 3) mean with a constant value increasing durations of the treatment. We tested beech, Turkey oak, oak, poplar, black locust and pine species and the developed schedules aimed high quality wood products. We publish the results of tests with the wood of beech (*Fagus sylvatica* L.) and Turkey oak (*Quercus cerris* L.) as follows. During our research we used logs from one certain production site. The so called juvenile wood around the pith was not totally removed, but it was minimized by removing the first 5-10 annual ring. The test boards made by this were cca. 35 mm thick and cca. 100 mm wide. The most important physical and mechanical properties were analysed using the European Norms (EN). From statistical aspect, the number of samples was 25 pcs and evaluation of data was made by the SPSS program.

2.1. Resistance to fungal decay

In laboratory conditions the resistance to fungal decay of the modified timbers is tested according to the standard EN 113. The special aim of this method is to determinate the protective effectiveness of the wood preservatives. During our research we made tests according to this standard, but sometimes we had to depart from it. In case of beech, we grafted mycelia of Turkey tail (*Coriolus versicolor*) to malt-agar soils. Turkey tail is the specie of fungi in the test standard, causing vigorous white rot. Its damage can be seen not only on stubs in the forests, but on timber in log yards and on timber built in humid places. Its appearance is very frequent and its common on nearly every broadleaved species. In case of trees having heartwood it attacks mainly the sapwood, but in case of sapwood trees, it attacks the matured parts as well. Decayed wood turns to yellowish colour and in this phase it can be crushed easily by hand. In case of Turkey oak, we grafted mycelia of oak maze gill (*Daedalea quercina*) to the soils. It causes brown rot and a common fungus causing decay on oak species. It attacks not only stubs in the forest, but the heartwood of freshly felled logs as well. In Turkey oak forests it is not so frequent, but it attacks the built-in timber of Turkey oak. Oak maze gill is not listed in the standard EN 113. We set the sizes of samples according to the volume of the research, so we had to decrease those as compared to the prescribed sizes of the standard's.

Figure 1. Placing samples on the fungi colonies in the grafting cabin

Samples were dried in 103 ±2°C temperature drying kiln and were measured with an accuracy of 0,01g. Placing of samples to Kolle-flask must be done in sterile environment. (fig.1.) After placing, the closed flasks were put in a thermostat, which assured constant 23°C inner temperature for the growing of the fungi. The standard test lasts 16 weeks, which was also reduced by us due to the decrease of the sample size and the wood weight placed in one flask. So the test duration was 12 weeks, after which the samples still were be able to be measured in whole, without crumbling. During measuring the fungal decay as compared to the original bone dry mass, practically the rate of mass loss is determined. After 12 weeks the samples must be measured after careful removal of the mycelia and repeated drying. The rate of fungal decay can be calculated by the formula as follows:

$$\Delta m_{fd} = \frac{m_o - m_{o,afd}}{m_o} \cdot 100$$

where: Δm_{fd} mass loss, the rate of fungal decay, [%]
m_o bone dry initial mass, [g]
$m_{o,afd}$ bone dry mass after fungal decay, [g]

The less the rate of decay, the more durable is the wood to the enzymatic decay of the fungus.

According to our tests, cca. 26% of the sapwood and 12% of the heartwood of the natural Turkey oak was decayed by the oak maze gill (*Daedalea quercina*). Modifying effect of the thermal treatment was recognised already in the case of 180°C treatments, but in case of 200°C treatments we succeeded to achieve fungal decay under 3%. Average rate of fungal decay of Turkey oak sapwood can be seen on the fig. 2.

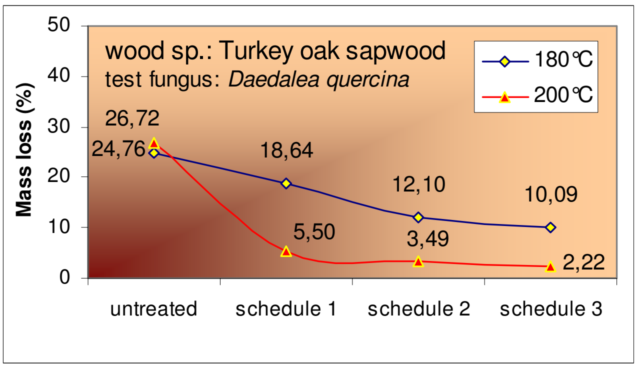

Figure 2. Average mass loss of Turkey oak sapwood (lines are for guiding the eyes)

In case of beech, treatments on 180°C didn't show significant changes of the rate of fungal decay. But the schedule 3 on 200°C caused obvious progress against the decay of the oak maze gill (fig. 3.).

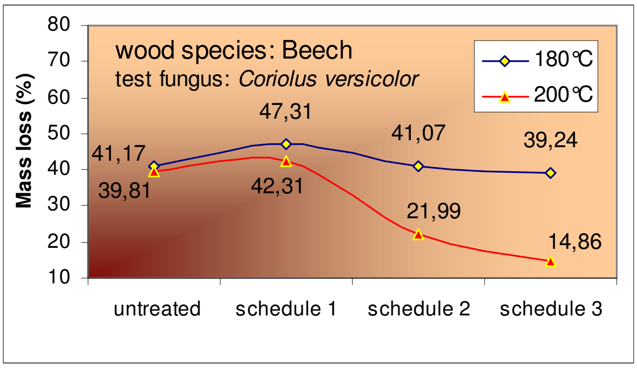

Figure 3. Average fungal decay of beech samples (lines are for guiding the eyes)

2.3. Other results - Physical and mechanical properties

Table Nr. 1 illustrates the changes of other tested properties in case of beech and Turkey oak heartwood. Generally it can be stated, that as a result of the physical and chemical changes in the wood during treatment, the treated wood becomes a modified, more compact structure, which is less hygroscopic, and parallel to this, it can be regarded as a less „moving", so called dimension-stable raw material. It can be seen, that the equilibrium moisture content under normal climate (u_e) decreases, and the dimension stability (DS) increases both in radial (r) and tangential (t) direction. During heat transfer, the partial decay of the wood components starts, together with the mass loss and shrinkage as well. Density in normal climate (ρ) showed more than 5% decrease at 200°C. About the degree of degradation, the modified darker colour of wood shows information as well. In the CIELab colour space system, the decrease of lightness (L*) was well recognizable, which showed good correlation to other physical and mechanical properties. The red (a*) component values increased in case of both species, while yellow (b*) component values slightly decreased. As a result of the complex modification the strength properties are changing too. Generally it can be stated, that the strength modifying effect of the thermal treatment is considerable. While the bending strength (σ_t) and the impact bending strength (w) vigorously decrease, on the other hand the compression strength along the grain (σ_c) increases by more than 25 % in case of beech and by 15-20 % in case of Turkey oak. Swelling anisotropy (a_d) and modulus of bending elasticity (E_h) of timbers slightly decrease, mainly in case of 200°C treatments.

Table 1. Physical and mechanical properties of thermally treated Turkey oak and beech

Properties measured (average values)		u_e(%)	ρ (kg/m³)	L*	a*	b*	DS_t (%)	DS_r (%)	a_d	σ_t (N/mm²)	E_h (N/mm²)	σ_c (N/mm²)	w (J/cm²)
Turkey oak	untreated	11,7	768,6	69,78	7,52	19,14			2,54	161,8	14138	83,75	10,22
	180°C - schedule 3	9,07	770,2	51,53	10,1	21,7	15,1	5,54	2,19	145,4	14661	84,25	7,75
	200°C - schedule 3	7,04	723,64	35,72	7,87	12,71	46,1	40	1,98	101,4	13080	98,01	6,25
Beech	untreated	12,34	674	81,02	5,2	19,23			2,28	125,9	12499	63,29	10,58
	180°C - schedule 3	10,91	672,27	56,16	11	22,04	7,8	7,95	2,3	124,8	12652	67,08	6,98
	200°C - schedule 3	7,12	613,62	38,34	9,29	15,71	40,2	31,2	2	101,1	11175	83,64	6,38

When testing the colour differences of sapwood and heartwood of Turkey oak, was recognised, that the total colour difference (ΔE) of the natural wood decreased vigorously after thermal treatment. While the total colour difference was 6,83 between the sapwood and heartwood in case of natural Turkey oak, it decreased to 1,77 on 200°C. According to the standard, if ΔE value is higher than 5, it means considerable colour difference, while a value between 1-2 means slight colour difference.

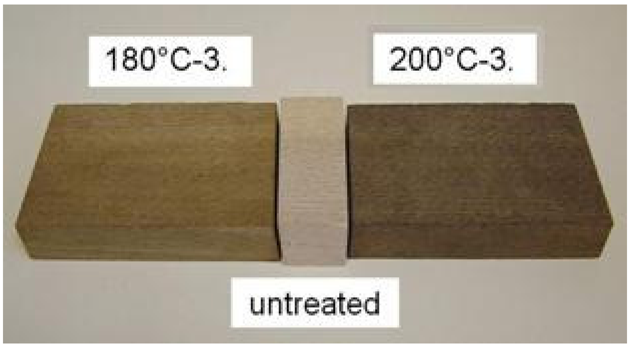

Figure 4. Colour changing of heartwood and sapwood of Turkey oak as an effect of thermal treatment

When tested beech wood with red heartwood, we recognized, that the heat treatment has favourable effect on the decreasing of colour difference, to a certain extent. The colour change of textures at the boundary surfaces of red heartwood is different, which causes an increasing of the inhomogenity in cases of treatments at 200°C. On the right side of the figure Nr. 5 it can be seen well, that certain parts with red heartwood, in the form of lighter stripes, significantly differ from the other textures. The measured value of total colour difference was 6,0 in case of the samples not treated, it decreased to 2,3 after treatment at 180°C, and increased to 3,82 after treatment at 200°C.

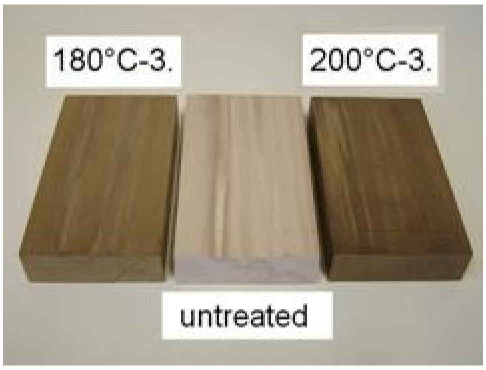

Figure 5. Colour homogenisation of beech with red heartwood as an effect of thermal treatment

3. SUMMARY

As an effect of the thermal treatment, structure, composition of wood materials is changing during different physical and chemical processes. As a result of the thermal effect the decomposition of chemical substances is starting, the wood material is shrinking and a more compact structure is forming. Due to the removal of –OH hydroxyl groups and spherical reasons, the higroscopy of the structure is decreasing, so the equilibrium moisture is also decreasing. As a result of this, dimension stability of thermal treated timber is increasing (NÉMETH 1998).

Based on our tests, it can be stated, that the rate of fungal decay may be decreased by thermal treatment and so the fungal decay resistance of these two species can be increased. It may result new outdoor applications of these materials, such as outdoor floorings, wall covers, etc. Thermal treatment has a favourable modifying effect on the colours, it not only

enables the reaching of darker shades of wood, but it may decrease the colour differences of certain wood parts. The fields of indoor application of treated timber may also be extended, e.g. wall covers, and decorating elements, etc. can be produced.
The modified colour changes on the effect of UV, similarly to the not treated wood (PATZELT et al. 2002).

Strength values have an important role when reaching the required colour, as those have significant influence of the durability of the future product. Changes of strength led us to the conclusion, that the colour modifying treatments should be made at the lowest possible temperature in order to meet the requirements for the future product. However we have to emphasize the fact that we carried out our treatments in normal atmospheric air, which is favourable for the oxidative decomposition processes. Selecting suitable treating agent is a key factor, having effect on the quality of the final product, on the degree of degradation of the wood, and on the costs, environmental effect etc. of the technology.

The experimental development was realized in the framework of the "Chemical-free wood preservation" project, at the site of SOKON Co ltd. As a result of the experimental development, a 10 m^3 volume vacuum drying kiln and a same size thermal treatment plant was developed.

Figure 6. Experimental development at SOKON Co ltd.

Acknowledgements: Authors render thanks to the Ministry of Economy and Transport for the support of GVOP – 3.1.1 „Chemical-free wood protection" and TÁMOP 4.2.1/b-09/1/KONV-2010-0006 project.

References:

NÉMETH, K. (1998): A faanyag degradációja. Mezőgazdasági Szaktudás Kiadó, Budapest

PATZELT, M. – STINGL, R. – TEISCHINGER, A. (2002): Thermische Modifikation von Holz und deren Einfluss auf ausgewählte Holzeigenschaften. Modifiziertes Holz –Eigenschaften und Märkte Band 3, VHÖ/IHF, BOKU Wien, 101-147

EN 113 Norm – Test method for determining the protective effectiveness against wood destroying basidiomycetes