University of West Hungary
Sopron

Theses of the doctoral (Ph.D.) dissertation

THE EFFECT OF THERMAL TREATMENT ON WOOD PROPERTIES WITH SPECIAL EMPHASIS ON THE WOOD RESISTANCE TO FUNGAL DECAY

Horváth Norbert

Sopron
2008

1. THE OPPORTUNENESS, ANTECEDENT AND AIMS OF THE RESEARCH WORK

Opportuneness

Heat treated wood, as a raw material is discovered again and more and more frequently used in the wood industry nowadays.

Choosing the most important industrial native tree species in Hungary, as Turkey oak (*Quercus cerris* L.), Pannónia poplar (*Populus* × *euramericana* 'Pannónia') and beech (*Fagus sylvatica* L.), is the specifics of the dissertation. The followings motivated the choice of these species.

- Hungary, with its 19,8% forest coverage, is often thought to have poor forest resources, but the forests consist of 87% hardwoods. Turkey oak is one of the most widespread species in Hungary, covering an area of 176.000 ha (11,4%). Poplar forests cover an area of 150.000 ha (9,6%) and yield 1,3-1,5 million m^3 of wood annually (23-25% of the total harvest). Pannónia poplar is a hybrid, bred by F. Kopecky at Sárvár. It is one of the most widely planted variety and its growth rate is similar to that of I 214 poplar. Beech forests occupy 102.545 ha (6,6%) and the annual timber harvest is from 500.000 to 600.000 m^3. These species have low fungal decay resistance.

- The thermally modified timber (TMT), as a new raw material for the wood industry became famous and took the European market by storm in the last decades. The production of TMT has been still increasing in Europe presently. For example the annual sales of ThermoWood® is made in Finland were achieved 72.000m^3 in 2007.

- The aim of this modification is to amend the wood properties that enlarge its application field. It's well known that by the thermal

modification some mechanical properties are reduced but the dimensional stability and the biological durability of wood is increased without adding outside chemicals / biocides to the wood. Therefore, thermally modified wood is discussed as a new material for several applications.

Antecedent

In the studied Hungarian and international literature the author could not find references to the heat treatment of Turkey oak and Pannónia poplar. The experiences in the field of thermal modification of beech need more enlargements recently. According to the European Norm (EN 350-2), the experimental woods except Turkey oak heartwood are considered to be a perishable wood. The application field of these woods is very small in outdoor. The production of thermal treated timber according to the demand of customers intensely increased in the last 10 years and Hungary needs import presently.

Recognizing the special demand of research in this field, the author have made laboratorial experiments at the Institute of Wood Science of the University of West Hungary in Sopron. This project, called “Preservatives-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 will be started at the SOKON Ltd. in the near future. The thermal treatments were carried out under atmospheric conditions. The temperature of the treatments ranged between 180-200°C and were 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 author hopes he can improve the literature of wood

modification with his study and will promote the economical development of Hungary.

Aims of the research

The primary aim of the presented study was to promote the production of thermal treated wood in Hungary. The main objectives of the study were the followings:

- allocating the treatment to be applied with studying the literature

- choosing the direction to develop experimental oven to treat wood by heat, and coordinating its development

- promoting the industrial production of TMT with experiences of the laboratorial dry treatments were made within the oven developed

- analysing the effect of the heat treatments developed with special emphasis on the protective effectiveness against wood destroying fungi and the statistical evaluation of physical and mechanical wood properties are important for industrial application

- establishing the new application fields of thermally modified woods investigated

2. MATERIALS AND METHODS

Investigated materials

Turkey oak (*Quercus cerris* L.)
Pannónia poplar (*Populus* × *euramericana* 'Pannónia')
Beech (*Fagus sylvatica* L.)

Specimens

The stems for the investigations came from one stand and the specimens were sawn out from their zone 130cm above the root level to decrease the deviation of the wood structure. The specimens for measuring physical and mechanical properties were applied with standard dimensions. The specimens were conditioned in a specific climate (φ=65%; t=20°C) before the measuring. 25 pieces of samples were used by each wood species and treatment. The sample's dimensions for determining the resistance against wood destroying fungi were 20×20×6 mm (radial × tangential × longitudinal) and 25 pieces of samples were used. The sample's dimensions for measuring the volumetric contraction and weight lost caused by the treatment were 20×15×35 mm (radial × tangential × longitudinal) and 5 pieces were applied in all cases.

Methods

Determining of fungal decay resistance

The wood decay tests were carried out using the EN 113. The incubation time applied for these tests has taken 12 weeks at 23°C. Sapwood

and heartwood of Turkey oak were investigated, too. Studied types of fungi per wood species:

Coriolus versicolor	by beech and Pannónia poplar
Daedalea quercina	by Turkey oak

Measuring the physical properties

The physical properties except contraction and weight lost were analysed using the norms:

-equilibrium moisture content according to MSZ 6786-2; 1988

-determination of density acc. to MSZ 6786-3; 1988

-measuring of colour (in CIE Lab system) acc. to MSZ 9619-3; 1975

-determination of swelling acc. to MSZ 6786-9; 1989

-contraction and weight lost caused by the treatment were measured with using digital calliper and balance

Measuring the mechanical properties

The mechanical properties were analysed using the norms:

-static bending strength according to MSZ EN 6786/5-70

-impact bending strength according to MSZ EN 6786/7-75

-compression strength along the grain acc. to MSZ EN 6786/8-71

3. SUMMARY OF THE RESULTS, THESE

3.1 Concerning the heat treatment

The author has developed a special dry heat treatment with several laboratorial experiments for improving the properties of Pannónia poplar, Turkey oak and beech.

3.2 Concerning the fungal decay resistance

The author has established that the resistance against *Coriolus versicolor* on Pannónia poplar increased with 40 percentiles and on beech with 25 percentiles after the dry treatment at 200°C.

The mass lost of heartwood and sapwood of Turkey oak caused by *Daedalea quercina* was decreased below to 3%. The same increase of the fungal decay resistance on sap- and heartwood of Turkey oak was ascribed by the author to the fungicide chemicals arising from the wood and the reduction of equilibrium moisture content.

3.3 Concerning the equilibrium moisture content

It was established by the author that the equilibrium moisture content of the investigated woods was decreased with 4-5% percentiles after the treatment at 200°C.

The reduction of the equilibrium moisture content was found as a factor to compensate the decrease of bending strength at 180°C.

The author has found the dry treatment carried out at 200°C very effective to reduce the swelling of the studied woods. The reduction was up to 30% in all cases.

The relation between tangential and radial swelling was found unchanged on Turkey oak and beech but in case of Pannónia poplar their quotient was reduced with 20%.

3.4 Concerning the contraction and the mass lost caused by heat degradation

It was established that the transversal contraction of the investigated woods was upper than 5% after the treatment carried out at 200°C.

The mass lost caused by heat degradation was found just 3-5% at 180°C but it was 10-15% after the treatment carried out at 200°C.

Despite of the contraction and mass lost caused by heat degradation, the wet density of the samples treated at 180°C was not changed. The author has established that the wet density of the investigated woods was reduced with 7-12% after the treatment carried out at 200°C.

3.5 Concerning the measuring of colour

The treatment carried out at 200°C resulted a decreasing of the brightness (L*) of the samples with about 50%.

The red (a*) and the yellow (b*) component of the colour were increased at the beginning of the treatment but from a level of degradation the values were decreased in all cases.

According to the investigation made by the author, the colour difference between sapwood and heartwood of Turkey oak can be reduced with 70-75% using the dry heat treatment.

Observing the behaviour of red heart in beech, was established that the treatment at 180° resulted a reduction of the colour difference with 60% but the colour of red heart became more inhomogeneous at 200°C.

3.6. Concerning the mechanical properties

The treatment carried out at 200°C decreased the static bending strength of Turkey oak with 40%, beech with 20% and Pannónia poplar with 34%.

The author has found the dry heat treatment at 200°C to exercise a significant influence on the impact bending strength. In case of Turkey oak and beech it resulted a decreasing with 40%, and by Pannónia poplar up to 70%.

It was established that the rate of the flat crash zone in the samples was increased at 200°C.

The author has ascribed the significantly increasing compression strength along the grain to the transversal contraction caused by the heat treatment.

3.7. Concerning the relationship between the observed properties

It was established that a very strong correlation was existed between the mass lost caused by the treatment and the other properties observed. The mass lost was considered one of the best markers of the physical and mechanical properties.

According to the author's findings, the simplest method to predict prospective values of fungal decay resistance, static bending strength, compressing strength along the grain, impact bending strength and swelling of Turkey oak, Panonia poplar and beech is measuring the brightness (L*).

The level of wood degradation was found independent from the temperature applied (180 and 200°C) to achieve it. The properties of the thermal treated wood were found only dependent on the degradation level.

4. POSSIBILITIES OF PRACTICAL UTILISATION

The results of this study may become a base of the dry thermal treatment of wood. The author's findings can be utilised to produce thermal treated Turkey oak, Pannónia poplar and beech with required quality. The better fungal decay resistance of heat treated timber can result new outdoor applications of these materials. The results determine new research directions for example analysing the emissions of gases and other chemicals in water, outdoor tests etc.The homogenization of colour increases aesthetical appearance of Turkey oak and red hearth beech. Therefore, they can be used in more and more fields. Modifications using heat may help substitute expensive exotic woods with Hungarian thermally modified timber. Therefore, it can be useful to revive Hungarian wood industry and economy. Parallel with growing esthetical appearance and fungal decay resistance of TMT the better anti swelling effect of this treatment increases the dimension stability. The findings concerning the contraction and swelling help calculate the material lost and the distance for lumber laying. The results about mechanical properties can be utilised for strength sizing of wooden constructions. According to the values of mass lost, decomposition products arising during the heat treatment can be quantitatively forecasted. They can strong influence the conditions of production. The measuring of colour of heat-treated Turkey oak, Pannónia poplar and beech can be utilised to predict physical and mechanical properties without expensive investigations.

5. PROCEEDINGS, PRESENTATIONS AND POSTERS

1. HORVÁTH N.:*„A faanyagvédelem jelentősége”-előadás RODOSZ - Konferencia Kolozsvár, felelős rendező Romániai Doktoranduszok Szövetsége, megjelent: Konferencia-kiadvány, 2003*

2. HORVÁTH N., CSUPOR K., MOLNÁR S.,*”Hitzebehandlung von Holz”-poszter, megjelent a 3. Europäische Thermoholz- Workshop konferencián, felelős rendező IHD-Dresden 2004*

3. HORVÁTH N., CSUPOR K., MOLNÁR S.:*”Hitzebehandlung von Zerreiche- Ergebnisse”-poszter, megjelent a 4. Europäische Thermoholz –Workshop Leipzig,konferencián, felelős rendez: IHD-Dresden 2005*

4. HORVÁTH N., CSUPOR K.: *„A fa termikus modifikálása”-poszter, megjelent a Ligno Novum-2004 alkalmából rendezett „ A minőségi hengeresfa feldolgozás fejlesztésének új kihívásai” konferencián Dr. Csupor Károly a „A faanyagok védelemének új lehetőségei” c. előadásához kapcsolódóan*

5. HORVÁTH N., CSUPOR K., MOLNÁR S., NÉMETH R.: *“The effect of thermal modification on the durability of wood against fungal decay”-poszter, megjelent: Proceedings of the 5th International Symposium Wood Structure and Properties '06. Technical University in Zvolen, Slovakia*

6. HORVÁTH N.: *„Termikus kezelés” c. alfejezet, megjelent könyvrészletként Molnár S., Várkonyi G. (szerk.)“Parketták, fapadlók” c. -könyvben, Szaktudás Kiadóház Zrt. Budapest, 2007*

7. HORVÁTH N., MOLNÁR S., NIEMZ P.: *„Untersuchungen zum Einfluss der Holzfeuchte auf ausgewählte Eigenschaften von Fichte, Eiche und Rotbuche”-cikk, megjelent: Holztechnologie (kiadó: IHD-Dresden) 2008/1 oldal: 10-15.*

8. HORVÁTH N., CSUPOR K., MOLNÁR S.: *„A hőkezelés hatása a Bükk (Fagus sylvatica L.) és a Csertölgy (Quercus cerris L.) tulajdonságaira, különös tekintettel a gombaállóságra” Faipar, a cikk szerkesztőségileg elfogadva, várható megjelenés 2008 májusa*

9. HORVÁTH N., CSUPOR K., MOLNÁR S.: *„Vegyszermentes faanyagvédelem, A hőkezelés hatása a bükk (Fagus sylvatica L.) és a csertölgy (Quercus cerris L.) faanyagok tulajdonságaira-cikk, Magyar asztalos és faipar 2008/4. 135-137.o.*

10. HORVÁTH N.: *„Untersuchungen an thermisch behandelten Laubhölzern" 5.Thermoholz WorkshopDresden-2008 április 24.-25. Konferencia-kiadvány2008 1.-6.o. kiadó: IHD- Dresden*

11. HORVÁTH N., CSUPOR K., MOLNÁR S.: *„Vegyszermentes faanyagvédelem - A faanyag hőkezelése" Hírfa 2008/4. 34. o.*

Doctoral School: József Cziráki Doctoral School of Wood Science and Technologies
Head: András Winkler DSc.

Program: Wood Science

Discipline: Science of Material Engineering and Technologies

Supervisor: Dr. Károly Csupor