EFFECT OF HEAT TREATMENT ON PHYSICAL AND MECHANICAL PROPERTIES OF SOME WOOD SPECIES

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ABSTRACT

In this article described research of physical and mechanical properties of some wood species, that were heat treated through Russian thermoconvective timber dryer (temperature up to 185 ºC) in comparison with untreated wood. Afterwards, moisture content, density, shrinkage, swelling, ultimate strength in compression parallel the grain, static bending strength, impact bending strength, static hardness, moisture absorption, water absorption of the specimens were measured and compared to the properties of untreated wood.

Key words: heat treatment, moisture content, density, shrinkage, swelling, ultimate strength in compression parallel the grain, static bending strength, impact bending strength, static hardness, moisture absorption, water absorption.

INTRODUCTION

At the present in the world is acute a problem of wood preservation. Wood is a renewed ecologically safety material which besides is easy for using. Therefore, people are trying to invent environmental friendly methods for wood preservation.

Heat treatment of wood at high temperatures ranging from 150 to 260 °C is one of the wood modification methods to improve dimensional stability, durability and other properties of timber (Seborg et al., 1953; Stamm, 1964; Hillis, 1984; Bourgois and Guyonnet, 1988; Syrjänen et al., 2000; Syrjanen and Oy, 2001; Anonymous, 2003). The production of heat-treated wood has increased rapidly in recent years (Ewert and Scheiding 2005). Several research groups have developed heat-treatment methods that are suitable for industrial applications (Boonstra et al. 1998; Viitaniemi et al. 1996; Weiland et al. 2003).

The Russian and the Ukraine market of thermally modified wood are currently in its initial stage of development. However, today there are more than twenty Russian companies involved in wood heat-treatment.

Properties of heat-treated wood of many species are being actively studied in different countries; the results of these researches are presented in many papers whereas the Russian and Ukraine production it is still poorly known.

In this study, three wood species: *(Pinus silvestris)*, oak *(Quercus robus L.)* and hornbeam *(Carpinus betulus L.)* were heat-treated using thermoconvective timber dryer at company „Litintermodom“ (Litin, Vinnitskaya region, Ukraine). After the heat treatment selected physical and mechanical properties: moisture content, density, shrinkage, swelling, ultimate strength in compression parallel the grain, static bending strength, impact bending strength, static hardness, moisture absorption, water absorption of the specimens have been measured and compared to the properties of untreated wood.

EXPERIMENTAL METHODS

The pine *(Pinus silvestris)*, oak *(Quercus robus L.)* and hornbeam *(Carpinus betulus L.)* wood specimens used in this study were obtained in Litin, Vinnitskaya region, Ukraine. Prior to heat treatment, the boards have already been kiln-dried. After that the boards were treated in thermoconvective heat treatment dryer (Russian name – SPCT, Fig. 1) from Russian company „Vacuumplus“ using various schedules. The dryer SPCT works on four temperature categories: A = 165 °C; B = 175 °C; C = 185 °C; D = 195 °C. The properties of the boards and key treatment parameters are presented in Table 1.

Fig. 1. The thermoconvective heat treatment dryer (Russian name – SPCT)

Table 1. Summary of the boards' properties and treatment conditions

Species	Number of trunks	Log dimension		Number of boards	Initial average MC [%]	Boards dimension [mm]	Maximum temperature [°C]	Total processsing time [h]	Duration at Maximum Temperature [h]
		diameter [cm]	length [m]						
Pine	30	32–34	4,5	30	6–8	4000x200x50	165	72	12
Oak	10	22–24	2,5	10	6–8	2500x140x35	175	72	12
Hornbeam	25	22–24	2,5	25	6–8	2500x140x35	175	72	12

After the heat treatment, the boards were visually evaluated for twists, cracks and other deformations. Only those boards that were free of defects were selected for further mechanical and physical property testing. The moisture content (MC) of the heat-treated boards was measured to be 3 %–4%. The untreated wood of the same species was used as a control.

The specimens for all research were cut from heat-treated and untreated boards, respectively (GOST 16483.0-89). The dimensions of the specimens used for moisture content (GOST 16483.7-71), shrinkage (GOST 16483.37-88), swelling GOST 16483.35-88), moisture absorption (GOST 16483.19-72) and water absorption (GOST 16483.20-72) studies were 20 x 20 x 10 mm, for density (GOST 16483.1-84) and ultimate strength in compression parallel the grain (GOST 16483.10-7) 20 x 20 x 30 mm, for static bending strength (GOST 16483.3-84) and impact bending strength (GOST 16483.4-73) 20 x 20 x 300 mm, for static hardness (GOST 16483.17-81) 50 x 50 x 50 mm. All statistical calculations were made respectively GOST standards, and based on the 95 % confidence level (Ugolev, 2005).

For testing used machine ZD10/90.

RESULTS AND DISCUSSION

The boards were visually checked after they were taken out of the dryer. The visible defects were found to be at minimum level. The overall performance of pine, oak and hornbeam was quite acceptable.

The changes in physical and mechanical properties of heart-treated pine, oak and hornbeam, compared to the properties of untreated wood of the same species are presented in Table 2. The changes were obtained by calculating the property difference between heat-treated wood and untreated same species as a percentage of untreated wood property.

Table 2. Changes in physical and mechanical properties of heat-treated (HT) pine, oak and hornbeam compared to the properties of untreated wood (UT) of the same species

Wood species	Type of treatment	Treatment temperature	Average moisture content at the moment of testing	Density	Shrinkage	Swelling	Ultimate strength in compression parallel the grain	Static bending strength	Impact bending strength	Moisture absorption	Water absorption
		[°C]	[%]	[kg/m^3]	[%]	[%]	[MPa]	[MPa]	[J/cm^2]	[%]	[%]
Pine	HT	165	4,50	426	8,76	11,52	59,06	79,99	4,02	13,4	164,5
	UT	20	11,85	423	10,00	15,83	48,99	87,63	4,48	16,9	164,1
Changing, %		-	-	+1	-12	-27	+21	-9	-10	-21	0
Oak	HT	175	4,12	595	10,09	17,70	73,36	105,04	7,09	8,9	98,1
	UT	20	13,02	523	10,18	20,07	48,87	79,96	5,71	16,8	113,2
Changing, %		-	-	+14	-1	-12	+50	+31	+24	-47	-13
Hornbeam	HT	175	3,69	683	14,79	17,32	95,47	155,20	5,15	10	79,5
	UT	20	13,57	617	18,19	25,45	47,96	121,64	8,05	18,6	88,4
Changing, %		-	-	+11	-19	-32	+99	+28	-36	-46	-10

Properties of heat-treated pine

Moisture content of heat-treated pine is 4,5 %, of untreated pine 11,85 %. Density of heat-treated pine increased 1 % compared to the untreated same species. Shrinkage and swelling of heat-treated pine decreased 12% and 27, respectively, compared to the untreated same species (Fig. 2, 3). Ultimate strength in compression parallel the grain increased 21 %. Static bending strength, impact bending strength of heat-treated pine decreased 9 % and 10 %, respectively. Moisture absorption of heat-treated pine decreased 21 %, to the untreated same species (Fig. 4). Water absorption of heat-treated and non treated pine stayed on the same level (Fig. 5). Longitudinal, radial and tangential hardness of heat-treated pine were increased after the heat treatment by 15 %, 15 %, and 2 %, respectively (Fig. 6).

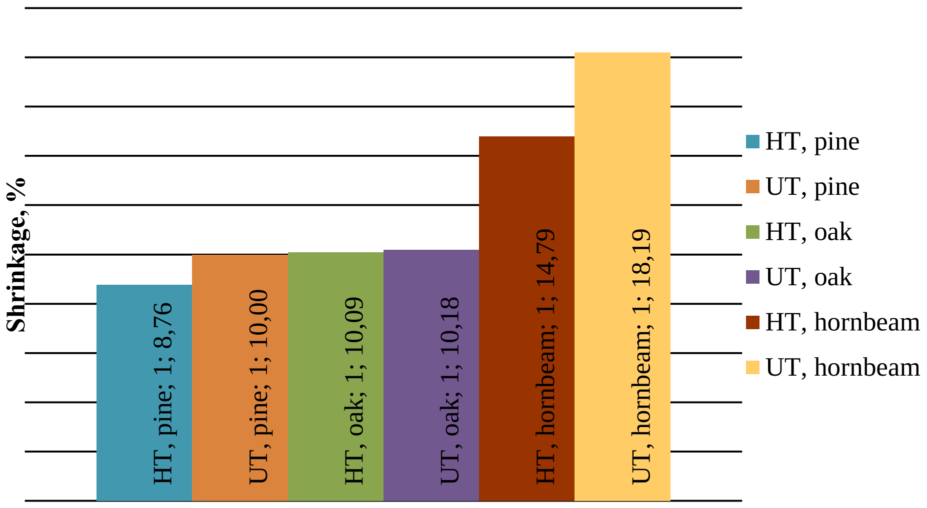

Fig. 2. Shrinkage of heat-treated (HT) and untreated (UT) wood

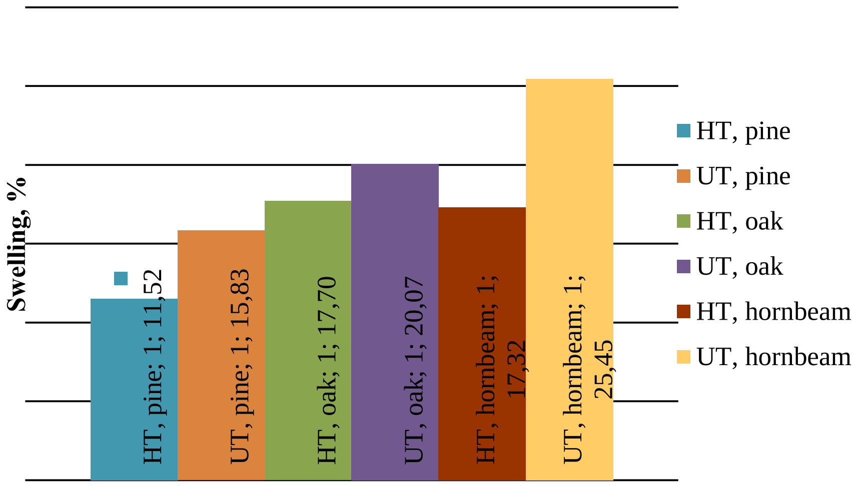

Fig. 3. Swelling of heat-treated (HT) and untreated (UT) wood

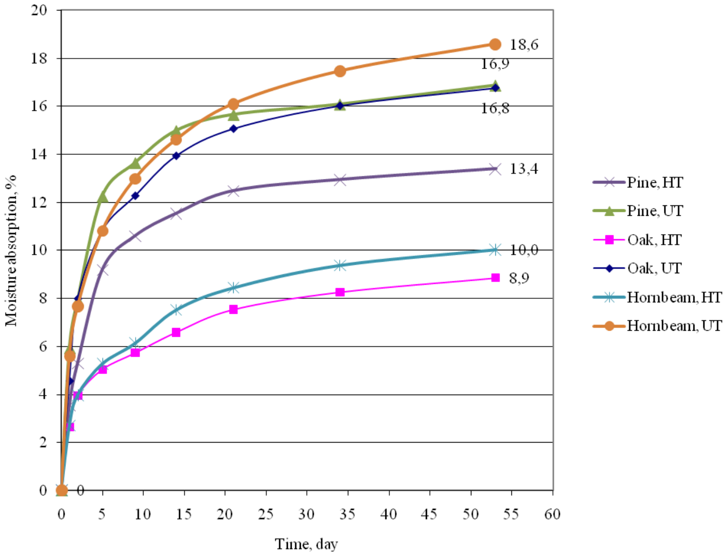

Fig. 4. Moisture absorption of heat-treated (HT) and untreated (UT) wood

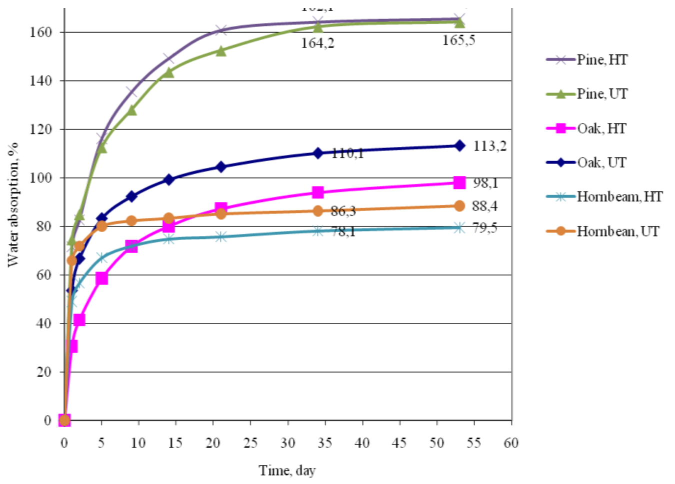

Fig. 5.Water absorption of heat-treated (HT) and untreated (UT) wood

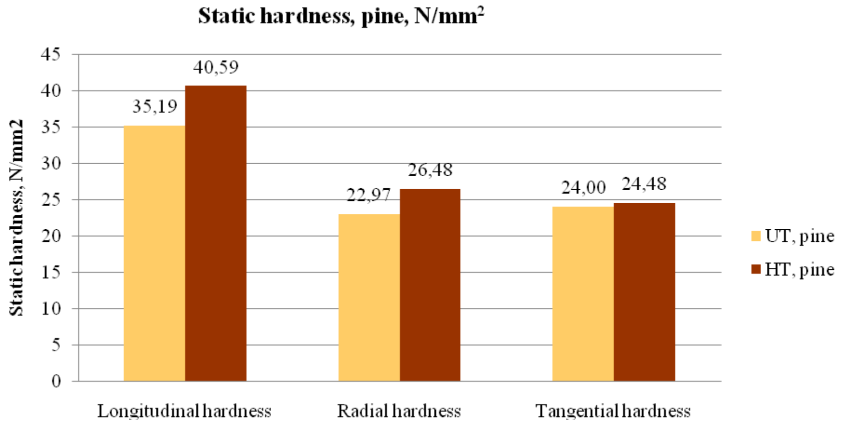

Fig. 6. Longitudinal, radial and tangential hardness of heat-treated pine

Properties of heat-treated oak

Moisture content of heat-treated oak is 4,12 %, of untreated wood 13,02 %. Density of heat-treated oak increased 14% compared to the untreated same species. Shrinkage and swelling of heat-treated oak decreased 1 % and 12 %, respectively, compared to the untreated same species (Fig. 2, 3). Ultimate strength in compression parallel the grain increased 50 %, compared to the untreated same species. Static bending strength, impact bending strength of heat-treated oak increased 31 % and 24 %, respectively. Moisture absorption and water absorption of heat-treated oak decreased 47 % and 13 %, respectively, compared to the untreated same species (Fig. 4, 5).

Properties of heat-treated hornbeam

Moisture content of heat-treated hornbeam is 3,69 %, of untreated wood 13,57 %. Density of heat-treated hornbeam increased 11 % compared to the untreated same species. Shrinkage and swelling of heat-treated hornbeam decreased 19 % and 32, respectively, compared to the untreated same species (Fig. 2, 3). Ultimate strength in compression parallel the grain increased 99 %. Static bending strength of heat-treated hornbeam increased 28 %. Impact bending strength decreased 36% compared to the untreated same species. Moisture absorption and water absorption of heat-treated hornbeam decreased 46 % and 10 %, respectively, compared to the untreated same species. (Fig. 4, 5).

CONCLUSIONS

The results of the initial tests carried out in this study show that the overall performance of the three species grown in Ukraine and treated by thermoconvective heat treatment method is acceptable. Generally, the reduction in water absorption of oak and hornbeam was smaller than that in moisture absorption. Water absorption of heat-treated and non treated pine stayed on the same level. Ultimate strength in compression parallel the grain and static bending strength of oak and hornbeam grow significant compared to the untreated same species. Density of heat-treated wood is also increased compared to the untreated same species. Shrinkage and swelling are reduced in heat-treated wood compared to the untreated same species. The results are affirmative especially for the hornbeam, which is widespread in Ukraine and has superior technological properties and high usage potential and is an important species in lumber industry.

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