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The Influence of Heating on Wood Hygroscopicity and Dimensional Stability

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The influence of thermotreatment on moisture exchange between wood and natural environment with variable air parameters as well as on dimensional stability of wood was studied. Experiments were carried out with pine wood samples in heated premises and outside. Prior to study the samples were heated at 60, 80, 100 and 120 °C temperature at the heating duration of 24, 48, 72 and 96 hours. It was found that moisture content of wood and its fluctuation as well as dimensional stability after thermotreatment completely depend on the heating temperature and duration. The higher the temperature and the longer the heating duration, the less hygroscopicity of wood is found, while the dimensional stability becomes higher. The effect of thermotreatment is especially observed on exploitable wood moisture content and its variations in premises. Actual moisture content in premises decreases even on 40 % as compared to the moisture content of untreated samples, while outside it decreases by 20 %. The change of moisture content in premises decreases almost twice, while outside on 1.7 times.

Keywords: wood, sorption, moisture content, heating, dimensional stability.

INTRODUCTION

Wood is one of the most widely used and strongest organic materials. Its use is rather versatile. Due to high mechanical strength, resistance, durability and light weight wood is used for light and strong constructions [1]. In some cases wood (hardwood) may be used in structures instead of metal elements [2]. Simple processing, lightweight and good heat insulating properties of wood products are very important for application in construction and furniture industry [3]. However, wood is a hygroscopic material. Due to various parameters of environment the moisture content, dimensions and geometrical shape of wood elements change essentially [4]. Various methods exist to reduce the hygroscopicity of wood. The most widespread among them are the coating of wood surface with finishing (they partially protect wood surface against mechanical damages and contamination) and painting of the ends of assortments (diffuse movement of moisture through the ends of assortments is 10 times more intensive than through the rest surface) [5]. The change of wood moisture content also depends on the drying method. Having exposed wood at high temperature (which is characteristic of artificial drying), its moisture absorption decreases [6].

The influence of thermotreatment on wood hygroscopicity was studied by K. Dyakonov, L. Petri, T. Konopliova, et.al. [7 – 9]. Studies were conducted under constant air parameters. It was found the stable moisture content of thermotreated wood totally depends on the drying temperature and duration. The "tougher'' is the processing regime, the lower is wood moisture content. Moisture content of the studied wood was lower or higher than room dryness (8 – 12 %). However, there is no data concerning wood heated at lower than 80 °C temperature. Under the climatic conditions of Lithuania only the change of air and chamber-dried pine wood moisture content was studied in heated premises and outside seeking to determine and compare sorption properties of the studied samples [10]. The investigations of influence of heating under different temperatures on wood hygroscopicity in variable conditions are limited.

The aim of the work is to determine and evaluate the influence of thermotreatment on wood hygroscopicity and dimensional stability under the climatic conditions of Lithuania.

EXPERIMENTAL

Pinewood, widely used in furniture production and construction industry, was investigated. The wood was air-dried down to 7 – 9 % of moisture content. The thickness of samples was 30 mm, width of 30 mm, length of 20 mm; conventional density was 420 – 500 kg/m^3. The samples were heated in a drying chamber at 60, 80, 100 and 120 °C temperature and the duration for 24, 48, 72, and 96 hours. The change of pine samples moisture content was studied in premises and outside. In outside conditions the samples were kept in the meteorological boxes, protected against direct precipitation, sunlight and wind. The changes moisture content of samples was evaluated by comparing weight of wood samples measured during each 10 days in summer (2000.06.06 – 06.15), 10 days in autumn (2000.11.15 – 11.24) and 10 days in winter (2001.02.05 – 02.14). Environmental parameters were defined by psychrometer (Table 1).

RESULTS AND ANALYSIS

To assess the influence of environmental parameters as well as temperature and duration of thermotreatment on wood hygroscopicity the changes of actual moisture content of wood samples and the changes of the mean of moisture changes per day have been investigated. The

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actual moisture content of wood (mean) with respect to the temperature is given in Table 2, Fig. 1 and Fig. 2, while mean change of the actual moisture content per day is presented in Table 3.

The increase of heating temperature from 60 to 120 ºC decreases wood moisture content from 1.1 times (outside) to 1.4 times (inside in winter). Moisture content of samples heated for 96 hours at 120 ºC temperature was lower in autumn and summer: in premises by 1.4, outside by 1.2 times; in winter: in premises 1.5, outside 1.1 times as compared with the moisture content of untreated samples. The influence of heating temperature on wood moisture may be expressed by the ratio 1:0.9 : 0.85 : 0.81 : 0.77 (comparing the moisture content of untreated samples with that of heated ones at 60, 80, 100 and 120 ºC temperature).

Table 1. Environmental parameters

Period	Temperature, °C		Relative humidity, %	
	T_{min}	T_{max}	ψ_{min}	ψ_{max}
Inside				
2000.06.06 – 06.15	19.6	24.8	46	65
2000.11.15 – 11.24	15.0	18.8	43	62
2001.02.05 – 02.14	11.2	17.2	20	40
Outside				
2000.06.06 – 06.15	12.8	26.2	34	90
2000.11.15 – 11.24	3.8	8.8	80	95
2001.02.05 – 02.14	–8.6	4.4	62	96

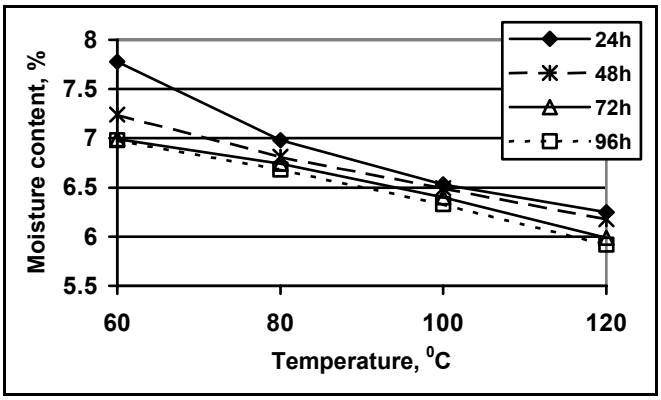

Fig. 1. Relationships of mean actual moisture content with respect to thermotreatment temperature and time (inside, summer)

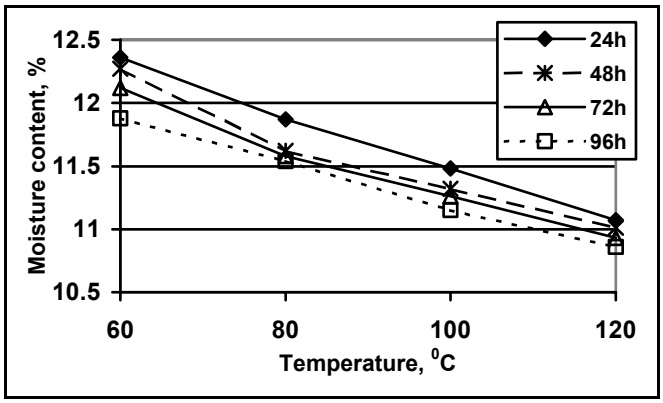

Fig. 2. Relationships of mean actual moisture content with respect to thermotreatment temperature and time (outside, summer)

Table 2. Actual moisture content of samples, %

Heating temperature, °C	Heating duration, h	2000.06.06 – 06.15		2000.11.15 – 11.24		2001.02.05 – 02.14	
		Inside	Outside	Inside	Outside	Inside	Outside
60	24	7.78	12.36	9.54	19	6.23	20.48
	48	7.24	12.27	8.96	18.66	5.82	20.26
	72	6.99	12.12	8.64	18.15	5.59	19.5
	96	6.98	11.88	8.62	17.89	5.53	19.42
80	24	6.98	11.87	8.52	17.79	5.47	19.13
	48	6.81	11.62	8.49	17.67	5.43	19.00
	72	6.74	11.58	8.43	17.6	5.39	18.85
	96	6.68	11.54	8.36	17.33	5.34	18.70
100	24	6.53	11.48	8.02	17.08	5.08	18.60
	48	6.49	11.32	7.84	17.01	4.94	18.51
	72	6.4	11.26	7.73	16.97	4.84	18.42
	96	6.33	11.15	7.67	16.91	4.68	18.41
120	24	6.25	11.07	7.59	16.83	4.58	18.22
	48	6.18	11.01	7.54	16.78	4.56	18.12
	72	5.99	10.93	7.47	16.66	4.42	18.02
	96	5.92	10.86	7.37	16.61	4.36	17.96
Untreated samples		8.44	13.3	10.5	19.85	6.66	20.53

Mean wood moisture content outside was even of 3.4 times (in winter) higher than inside.

The change of moisture content per day was also evenly decreasing with increasing heating duration and temperature. The increase of heating temperature from 60 to 120 ºC, decreases the hygroscopicity of wood: in summer by 1.3; in autumn by 1.5 – 1.6; in winter by 1.2 – 1.3 times. The hygroscopicity of samples heated for 96 hours at 120 ºC temperature was lower in summer by 1.5; in autumn by 1.7 – 1.9; in winter by 1.3 – 1.5 times as compared to the hygroscopicity of untreated samples. The influence of heating temperature on the change of moisture content in samples per day may be expressed by the ratio 1 : 0.95 : 0.94 : 0.93 : 0.93 (comparing the untreated samples with the heated ones at 60, 80, 100 and 120 ºC temperature). The longer the duration of wood heating, the lower was the actual moisture content per day and less variation in its values appear. Under heating duration of 24, 48, 72, 96 hours the ratio of actual moisture content and its change was 1 : 0.98 : 0.97 : 0.96 respectively.

The reduction of moisture absorption is caused by adsorption (first of all due to monomolecular, later due to polymolecular). It is explained by the fact that when wood is exposed at the high temperatures, some free hydroxyl groups of cellulose molecules create bonds between themselves. Therefore, such groups cannot act as potential sorption centres. In the capillary condensation no changes occur. Besides, this decrease in hygroscopicity differs for different species of wood [7].

If after thermotreatment the hygroscopicity of wood decreases, due to lowered swelling and shrinkage the variation in samples dimensions also decreases. Seeking to evaluate the increment of wood stability after thermo-treatment, some pine samples after heating at 60, 80, 100 and 120 ºC temperature for 24, 48, 72 and 96 hours were dried up to absolutely dry mass and the dimensions were measured in tangential and radial directions. Afterwards were soaked until moisture content exceeded 30 % and again measured in tangential and radial directions, while some part of them, on the contrary, first were soaked and then dried.

Changes of extreme dimensions measured (shrinkage and swelling) in tangential and radial directions obtained during the experiment are presented in Tables 4 and 5.

Table 3. Mean change of sample moisture content per day, %

Heating temperature, ºC	Heating duration, h	2000.06.06 – 06.15		2000.11.15 – 11.24		2001.02.05 – 02.14	
		Inside	Outside	Inside	Outside	Inside	Outside
60	24	0.30	1.10	0.18	0.25	0.37	0.58
	48	0.29	1.09	0.17	0.25	0.35	0.56
	72	0.28	1.08	0.17	0.24	0.35	0.56
	96	0.27	1.06	0.16	0.24	0.34	0.55
80	24	0.27	1.04	0.16	0.23	0.34	0.54
	48	0.26	1.02	0.15	0.21	0.32	0.52
	72	0.26	1.00	0.15	0.21	0.32	0.51
	96	0.26	0.92	0.14	0.21	0.31	0.50
100	24	0.25	0.90	0.13	0.20	0.30	0.49
	48	0.25	0.89	0.13	0.20	0.29	0.49
	72	0.24	0.89	0.12	0.19	0.29	0.49
	96	0.24	0.87	0.11	0.19	0.29	0.49
120	24	0.23	0.87	0.11	0.18	0.29	0.49
	48	0.23	0.86	0.11	0.17	0.28	0.48
	72	0.22	0.85	0.11	0.16	0.27	0.47
	96	0.21	0.83	0.10	0.16	0.27	0.47
Untreated samples		0.31	1.19	0.19	0.27	0.4	0.6

Table 4. Changes of dimension in tangential direction, mm

Heating temperature, ºC	Heating duration, h			
	24	48	72	96
60	2.80	2.75	2.74	2.71
80	2.77	2.71	2.695	2.68
100	2.74	2.70	2.68	2.67
120	2.71	2.67	2.65	2.635
Untreated samples		2.835		

Table 5. Changes of dimension in radial direction, mm

Heating temperature, ºC	Heating duration, h			
	24	48	72	96
60	1.49	1.465	1.445	1.42
80	1.46	1.435	1.41	1.39
100	1.43	1.41	1.39	1.37
120	1.4	1.38	1.365	1.35
Untreated samples		1.55		

The stability of samples dimensions heated for 96 hours at 120 ºC temperature was 8 % higher in tangential direction, while in radial direction 14 % greater as compared to the dimensional stability of the untreated samples. The influence of heating temperature on wood dimensional stability in tangential direction compared to the untreated samples obtained at 60, 80, 100, 120 ºC temperature may be expressed by the ratio 1 : 0.94 : 0.92 : 0.90 : 0.89. In radial direction it was 1 : 0.94 : 0.92 : 0.90 : 0.89.

The longer the duration of heating, the less the change of wood dimensions. Under heating duration of 24, 48, 72 and 96 hours the ratio of dimensional stability was 1 : 0.98 : 0.97 : 0.96.

CONCLUSIONS

The moisture content of wood and its variations after thermotreatment completely depends on the heating temperature and duration. In order to decrease possibility of the both moisture absorption and evaporation during application wood must be heated. The higher temperature and the longer heating , the lower wood hygroscopicity can be reached. The effect of thermotreatment on the moisture content and its changes especially was observed for wood located in premises. Actual wood moisture content inside decreases even on 40 % compared to the untreated ones, while outside that decreases only on 20 %. The change of moisture content per day in premises decreases almost twice, while outside on 1.7 times. However, it should be noted that exposure under high temperatures worsen wood mechanical properties and cause changes in the appearance (darkening).

Dimensional stability of wood assortments also depends on the heating temperature and duration. The higher heating temperature and the higher heating duration, the higher dimensional stability can be obtained.

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