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The influence of high temperature wood drying conditions using air-steam mixture on its properties

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Abstract: *The influence of high temperature wood drying conditions using air-steam mixture on its properties*. The results of properties change of beech wood after drying process are presented. The wood taken to experiments was from northern part of Pomeranian region in Poland. Before the main high temperature drying process using air-steam mixture, wood was initially dried in an open air conditions. The high temperature drying process was conducted at temperature 120°C, humidity 48%, flow rate of drying medium 2.5m/s and atmospheric pressure. It allowed to reveal the effects of wood air-steam mixture and their temperature drying on wood properties. It has been recognized that air-steam mixture drying cause of the properties changes of analyzed wood specie, such as deformation and stress.

Keywords: wood drying, high temperature drying, wood properties

INTRODUCTION

High temperature drying of wood is defined as a method of drying in the environment where the temperature is equal or higher than 100°C (***Obataya et al. 2006, Perré 1999***). Higher temperature than 100°C is applied only when wood moisture content decreases below FSP (Fibre Saturation Point**)**. Therefore drying fresh broadleaved wood is a risk. At moisture content about 40-60% occurrence of internal cracks (collapse) and external cracks can be observed. Wood changes color and then all kinds of cracks can be noticed (***Klement, Detvaj 2013***). Drying intensification, which occurs at high temperature, affects the shortening drying time of duration of the process in comparison with hot air drying one (***Keylwerth 1952, Gard, Riepen 2008***).

In the process of manufacturing timber, drying is the single most costly step in terms of energy consumption and time. High temperature drying process through a mixture of air and superheated steam is a way of drying, that reduces the consumption of heat and electric energy. Decreasing energy consumption and processing time are to important current objectives of the timber drying industry. Extensive research has been done and is still being done to determine the optimal drying strategy to achieve the required timber quality at minimum cost. The variability of wood properties further complicates drying. Each species has different properties, and even within species, variability in drying rate and sensitivity to drying defects impose limitations on the development of standard drying procedures. The interactions of wood, water, heat and stress load during drying are complex. In practice the local drying conditions in the experimental drying kiln strongly interact with the heat and mass transport in the wood.

The proper conduct of the drying process allows faster extraction of water (***Obataya et al. 2006***. Other benefits, possible to mention, are decrease in the equilibrium moisture content of wood or greater resistance to degradation (***Langrish et al. 1992***, ***Langrish et al. 1993, Pang et al***. 2001, ***Sun et al. 2000***). The disadvantages of this method are surface colouration, stress of dried material as a consequence of high temperature, drop in the mechanical properties (***Barański 2014***), complicated dryer sealing and corrosive effects.

MATERIALS

The experiments of drying process were performed of the laboratory convectional drying kiln with 1.1 m^3 load capacity of samples. The superheated steam was produced by steam generator, which allowed keeping constant temperature and relative humidity inside drying kiln. Steam circulation inside the experimental chamber was forced by fan. The speed of drying medium could be changed up to 2.5 m/s. The temperature inside drying chamber during experiments was 120°C.

The system, which controls drying process, is located outside the drying chamber. It contains 6 thermocouples to measure respectively temperature inside the kiln and temperature inside drying wood samples in 3 chosen locations (points in the sample Fig.1). This system also includes the psychrometer to measure the value of huminidity of environment inside the drying chamber.

All parameters were monitored using the computer program DISPLEJ and then acquisitioned. Moisture content of dried wood was measured by gravimetric method. The experimental rig consisted of a weight that allowed measurement of the mass sample during the drying process. The applied method of measuring the moisture content by gravimetric method enabled more accurate measurement for the method commonly used in the industry, which uses the moisture content sensors based on resistance.

Material used in the experiment was beech wood (Fagus silvatica L.) originating from the northern part of Pomerania region in Poland. Samples from a wood beam length of 4,5 m were cut with 25 mm x 70 mm x 600 mm dimensions, Fig. 1.

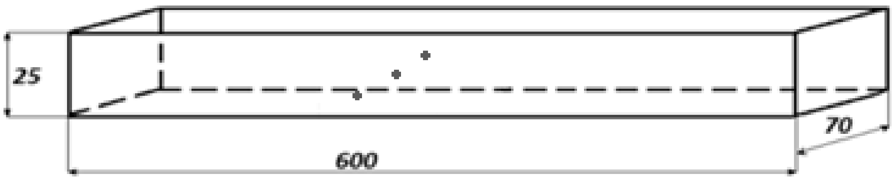

Fig. 1 The view of simple three samples prepared for drying.

Before the experiments all dimensions - high, width and length of samples were measured. Before the start of the drying process, in order to determine its moisture content before drying (by gravimetric method), from wood samples were taken clippings. The moisture content of wet wood in each piece was measured. Fig. 2 shows the method of taking the piece from sample of testing wood.

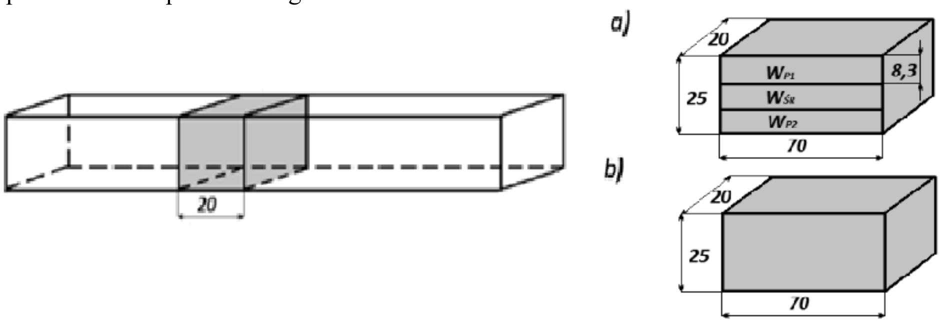

Fig. 2 The view of moisture content measuring scheme in wood sample:
a) wet wood moisture content measurement in each piece,
b) wood moisture content measuring before drying by using the gravimetric method.

RESULTS

During the experiment, two samples of beech wood were dried. As a result of the research, graphs of temperature variability (Fig. 3) and the moisture content changes of wood during the course of the research (Fig. 4) were prepared.

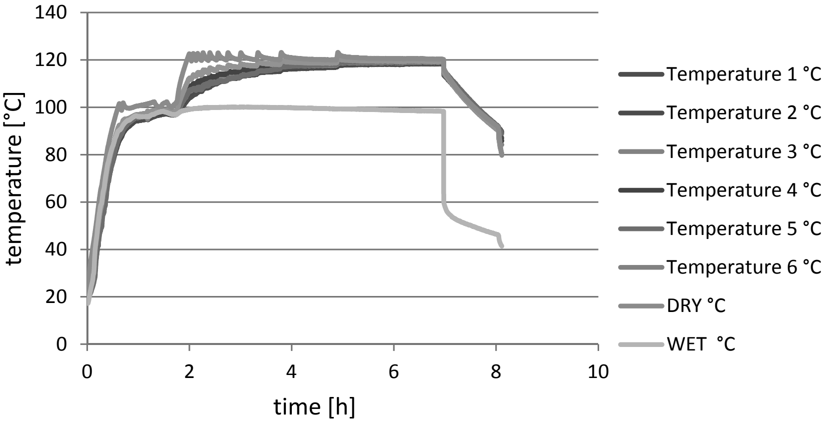

Fig. 3 The changes of temperature in the drying chamber and in the wood during the drying process.

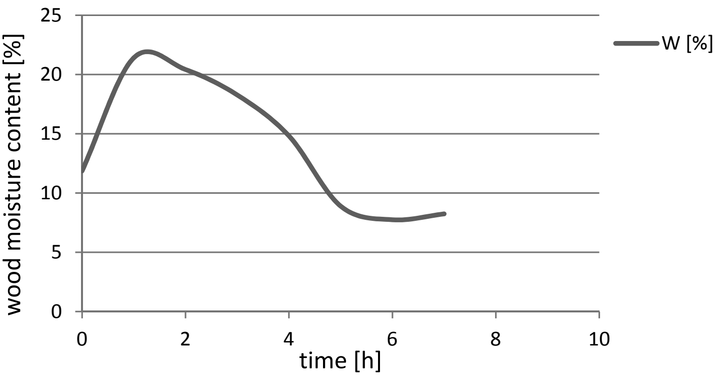

Fig. 4 The changes of moisture content in wood during drying process.

The first step of analyzing the quality of the wood after the drying process is based on a comparison of wood moisture content in each piece before and after drying (Fig. 4).

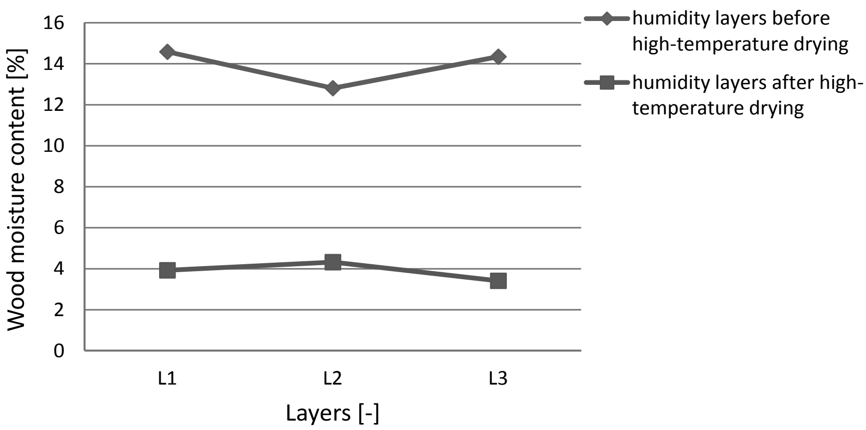

Fig. 5 The changes of moisture content in each piece of wood before and after drying.

To determine the level of stress occurring in the dried wood, so called "test of fork", the second step was performed, was (Fig. 5). The quality of wood after drying, using the equation (1), was analyzed:

$$K = \frac{(h-s)\cdot 100}{h\cdot b} \cdot 100\ [\%], \tag{1}$$

where:

h - width of sample [mm],
b - high of sample [mm],
s - distance between forks [mm].

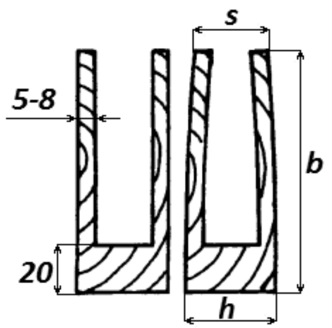

Fig. 6 The view of simple, showing the samples of wood using to "test of fork" and the dimensions measured.

The obtained results are presented in the table. 1.

Tab. 1 Results of quality wood in terms of stress.

TEST OF FORK					RATING
No of sample	**Width**	**Height**	**Distance between forks**	**Quality index of wood**	
	h [mm]	b [mm]	s [mm]	K [%]	
1	25.4	66.6	24.2	7.5	high quality
2	25.6	67	24.7	5.4	high quality

As we can see, the differences in distance between forks "s" are not so great, only 0.5 mm. According to above equation, the test of dried wood shows high quality of material, which is determined by quality index "K".

The next step, so called "rez-test", was performed. The aim of it was to determine the intensity of deformations occurring in the dried wood (Fig. 7). The results of the quality of the dried wood in terms of deformation are shown in Tab. 2.

Tab. 2 Results of quality wood in terms of deformations. (pod względem)

REZ - TEST		**RATING**
No of sample	**Gap dimension** s [mm]	
1	0.56	exclusive wood
2	0.33	exclusive wood

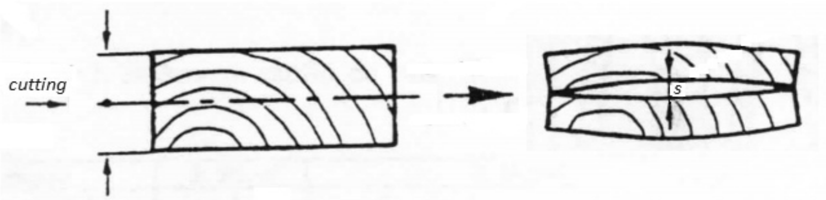

Fig. 7 The view of simple, showing the samples of wood with dimensions 25,5 x 67 x 25mm, using to “rez-test”.

After this test we can assume that drying process didn't influence on internal stress of wood. The value of gap dimension "s" is small but the differences between samples occur.

CONCLUSIONS

The “test of fork” and “rez-test” show that there were no bigger deformation and stress, which proves the well-chosen drying parameters and good quality of considered material. Moisture distribution in the each piece of beech wood samples tested does not deviate from the norm.

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Streszczenie: *Wpływ warunków suszenia drewna bukowego w wysokiej temperaturze z wykorzystaniem mieszaniny powietrzno-parowej na jego właściwości.* W artykule przedstawiono analizę zmian własności drewna bukowego po przeprowadzeniu wysokotemperaturowego procesu suszenia. Suszonym drewnem było drewno bukowe pochodzące z Pomorza, północna części Polski, regionu. Główny proces suszenia w atmosferze powietrza i pary przegrzanej poprzedzony został suszeniem materiału na wolnym powietrzu. Suszenie przebiegało pod ciśnieniem atmosferycznym w temperaturze 120°C, wilgotności 48% i przy prędkości przepływu czynnika suszącego wynoszącego 2.5 m/s. Przeprowadzone testy jakości drewna po suszeniu umożliwiły przedstawienie wpływu wykorzystania mieszaniny powietrzno-parowej jako czynnika suszącego na właściwości badanego drewna. Stwierdzono, że zastosowanie mieszaniny powietrza i pary przegrzanej o danych parametrach suszenia przyczyniło się do zmian właściwości drewna bukowego, takich jak deformacja oraz naprężenia.

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