



THE INFLUENCE OF DRYING PARAMETERS ON WOOD PROPERTIES

Jacek Barański – Maciej Wierzbowski

Abstract

*Results of influence of gas-steam mixture drying process on wood mechanical properties are presented. Wood species, namely pine (*Pinus sylvestris* L.) and beech (*Fagus silvatica* L.) from the northern part of Pomerania region in Poland, were subject of steam kiln-drying process in a laboratory kiln specially arranged for that reason. Measurements of the global coefficient of elasticity and bending strength for steam dried and air dried samples, as a reference, allowed to reveal the effect of wood steam drying and its temperature level on mechanical properties of wood. It has been recognized that steam wood drying causes a decrease of the mechanical properties of the wood. While the colour changes have been observed directly after process, changes in mechanical properties have to be measured. During experiments global time of drying process was shorten and satisfactory results were obtained.*

Key words: *wood drying, high-temperature drying, wood moisture content, wood properties*

INTRODUCTION

Wood lumber drying is one of the most time and energy consuming steps in processing wood products. The anatomical structure of wood limits how rapidly water can move through and out of wood. In addition, the sensitivity of the structure limits the drying rate; rapid drying causes defects such as surface and internal checks, collapse, splits and warp. Drying time and susceptibility to many drying defects increase at a rate that is more than proportional to wood thickness. 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.

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 [1, 2, 3]. Drying intensification, which occurs at high temperature, affects the total time of duration of the process in comparison with hot air drying, [4, 5]. The proper conduct of the drying process allows faster extraction of water [1, 2]. Other benefits, possible to mention, are decrease in the equilibrium moisture content of wood or greater resistance to degradation [6, 7, 8, 9]. The disadvantages of this method are: drop in the mechanical properties [10, 11, 12, 13, 14] and need to specific management of the drying process.

MATERIALS AND METHODS

The drying process was conducted in the experimental kiln of 0.55 m³ load capacity. The heat was supplied to the kiln by both fan's engine and heat exchanger, supplied by exhaust gases from combustion chamber. The heat exchanger allows to keep steam environment inside kiln. Steam circulation inside the kiln was forced by circulation fan with speed regulation up to 5.0 m/s. Fan and heat exchanger were located in the working area of the kiln separated from the drying area by the wall. The two chimneys on the roof of the kiln control environment conditions inside. The temperature inside kiln was set to 80°C and 110°C.

The control system is located outside the kiln. It includes 4 thermocouples to measure dry-bulb temperature inside the kiln and temperature inside wood in 3 chosen locations. This system also includes 8 moisture content sensors used to measure the level of wood moisture and 1 sensor to measure humidity of environment inside the kiln.

Materials used in the experiment were pine (*Pinus sylvestris* L.) and beech (*Fagus silvatica* L.) wood originating from the northern part of Pomerania region in Poland. From a wood beam length of 4.5 m samples were cut with 70 × 70 × 1500 mm dimensions, Fig. 1. Before experiments all samples were measured.

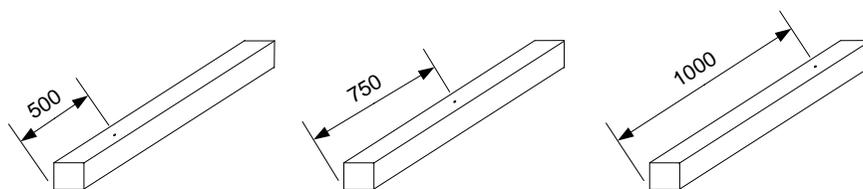


Fig. 1. The view of sample's place for moisture measurement.

The average initial moisture content of the pine samples ranged between 31.8 - 51.2% and of the beech samples between 70.6 - 87.3%, Table 1.

Table 1. Results of wood moisture content measurements before drying.

Samples		Average moisture content [%]	Samples		Average moisture content [%]
Pine air dried	1	50.1	Beech air dried	1	74.3
	2	50.4		2	80.1
	3	37.0		3	87.3
	4	31.8		4	86.4
	5	34.2		5	76.9
Pine high temperature dried (80°C)	1	51.2	Beech high temperature dried (80°C)	1	70.6
	2	49.6		2	76.9
	3	48.7		3	87.1
	4	34.0		4	83.7
	5	56.7		5	79.8
Pine high temperature dried (110°C)	1	46.4	Beech high temperature dried (110°C)	1	76.5
	2	46.5		2	75.8
	3	42.0		3	86.2
	4	33.9		4	84.0
	5	34.5		5	79.2

All samples were dried in three ways: conventional (air) and accelerated (steam) with 80°C and 110°C using an automatic control system. After drying process, the samples were checked, i. e. all dimensions and moisture content. To measure moisture content hygrometer type WRD100 of Tanel Company was used, which is based on inductive method.

RESULTS

The final moisture content of samples during air drying vary from 9.7 to 18.3% for pine and from 6.0 to 16.8% for beech, table 2.

Table 2. Results of wood moisture content measurements after drying.

Samples		Average moisture content [%]	Samples		Average moisture content [%]
Pine air dried	1	15.8	Beech air dried	1	10.7
	2	17.0		2	12.5
	3	18.3		3	14.0
	4	17.2		4	16.8
	5	19.0		5	13.4
Pine high temperature dried (80°C)	1	14.4	Beech high temperature dried (80°C)	1	6.2
	2	14.8		2	6.9
	3	14.7		3	6.3
	4	15.2		4	6.6
	5	16.9		5	6.1
Pine high temperature dried (110°C)	1	10.9	Beech high temperature dried (110°C)	1	6.0
	2	10.8		2	6.0
	3	9.7		3	6.0
	4	9.9		4	7.8
	5	11.0		5	6.0

After drying process, the tests of global coefficient of elasticity and bending strength for steam dried and air dried samples, as a reference, have been performed.

Number of elements for test was determined according to EN 1995 (Eurocode 5) "Designed of timber structures". To measure moisture content hygrometer type MMC 210 of Wagner company was applied, which is based on inductive method.

Measurement of the global coefficient of elasticity, when bending, was conducted according to PN-EN 408:2004 as presented in Fig. 2.

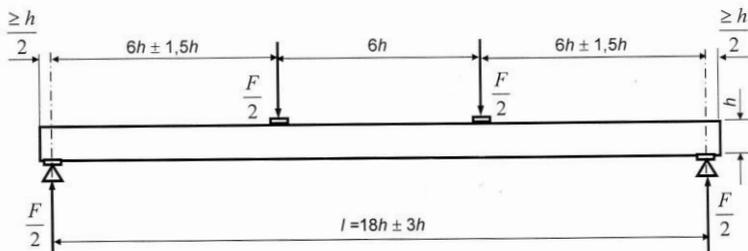


Fig. 2. Scheme of static test according to PN-EN 408:2004.

For experiments strength machine Tiratest 2030 was applied.

As an example of nature of destruction of wood sample after test, the beech prism is presented below, Fig. 3.



Fig. 3. View of the nature of beech sample destruction.

In table 3 the results of mechanical properties of analyzed wood species after conventional and accelerated drying are presented. All tests were performed according to the same methodology.

Table 3. Mechanical properties of tested elements after accelerated and conventional drying process.

Name of wood	Average destructive force [N]	Average strength - bending [N/mm ²]	Average global elasticity coefficient [N/mm ²]
Pine dried at 110°C	12418.93	39.50	10735.74
Pine dried at 80°C	13802.51	41.14	11315.31
Pine conventional air dried	12768.47	40.25	11550.52
Beech dried at 110°C	16639,35	66,45	12632,53
Beech dried at 80°C	18683,70	75,61	13546,24
Beech conventional air dried	20002,17	70,57	12460,15

CONCLUSIONS

The results obtained from tests show that drying under high temperature conditions affect the moisture content in wood. The difference in moisture content in samples dried in the air is greater than in samples dried under high temperature conditions using steam. Differences between measured moisture content of wood dried under conventional air varies from 15.8 to 19% for pine and from 10.7 to 16.8% for beech. In contrary measured moisture content of wood dried under high temperature varies from 14.4 to 16.9% for pine and from 6.1 to 6.9% for beech at temperature of drying 80°C, and from 9.7 to 11% for pine and from 6 to 7.8% for beech at temperature of drying 110°C.

The strength bending of pine wood elements dried at 110°C is 39.5 N/mm², for items with dried at 80°C is 41.14 N/mm². The same parameter in the control elements is 40.25 N/mm². The global elasticity coefficient for wood dried at 110°C is 10735.74 N/mm², for items dried at 80°C is 11315.31 N/mm² and for control elements is 11550.52 N/mm².

The strength bending of beech wood dried in 110°C is 66.45 N/mm², and for elements dried in 80°C is 75.61 N/mm². Control elements have bending strength equal to 70.57 N/mm². The global elasticity coefficient of wood dried at 110°C is 12632.53 N/mm², while for elements dried at 80°C is 13546.24 N/mm². The control elements have coefficient equal to 12460.15 N/mm².

Differences in values of mechanical properties are not relevant. It is necessary to carry out further experiments to set exact drying parameters under high temperature conditions.

ACKNOWLEDGEMENT

The financial assistance of Ministry of Science and Higher Education, Poland, Grant no N N 508 629840 is kindly acknowledged.

REFERENCES

- [1] SÁNDOR, P *et al.*: „Effect of high temperature treatment on the mechanical properties of birch (*Betula papyrifera*)”. Wood Science Technology, 2006.
- [2] OBATAYA, E *et al.*: „Effects of high temperature kiln drying on practical performance of japan cedar wood (*Cryptomeria japonica*) I: changes in hygroscopicity due to heating”. Journal of Wood Science. 2006.
- [3] PERRÉ, P.: „How to Get a Relevant Material Model for Wood Drying Simulation?” COST ACTION E15 - Advances in drying of Wood, 1st Workgroup in Edingurgh. 13-14th Oct 1999.
- [4] KEYLWERTH, R.: „Hochtemperatur-Trockenanlagen”. European Journal of Wood and Wood Products, 1952.
- [5] GARD W.F., RIEPEN M.: „Super-heated drying in Dutch operations”. Conference COST E53, Delft, the Netherlands, 29-30 October 2008.
- [6] LANGRISH, T. A. G., KHO, P. C. S., and KEEY, R. B.: „Experimental measurements and numerical simulation of local mass-transfer coefficients in timber kilns”. Drying Technology, 10, 753-781, 1992.
- [7] LANGRISH, T. A. G., KEEY, R. B., KHO, P. C. S., and WALKER, J. C. F.: „Time-dependent flow in arrays of timber boards: Flow visualization, mass-transfer measurements and numerical simulation”. Chemical Engineering Science, 48 (12), 2211-2223, 1993.
- [8] PANG S., SIMPSON I.G., HASLETT A.N.: „Cooling and steam conditioning after high-temperature drying of *Pinus radiata* board: experimental investigation and mathematical modeling”. Wood Science and Technology 35 (2001), Springer Verlag 2001, s.487-502

- [9] SUN, Z. F., CARRINGTON, C. G., and BANNISTER, P.: „Dynamic modeling of the wood stack in a wood drying kiln”. *Chemical Engineering Research and Design, Transactions Institution of Chemical Engineers, Part A*, 78, 107-117, 2000.
- [10] WIERZBOWSKI M., BARAŃSKI J., STAŚIEK J.: „Gas-steam mixture wood drying”. COST E53 Meeting „Quality Control for Wood and Wood Products” : EDG Drying Seminar „Improvement of Wood Drying Quality by Conventional and Advanced Drying Techniques”, Bled, Slovenia, April 21st-23rd, 2009.
- [11] WIERZBOWSKI M., BARAŃSKI J., STAŚIEK J.: „Suszenie drewna mieszaniną parowo-gazową”. *Termodynamika w nauce i gospodarce*. Wrocław, 2008 (in polish).