Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 86, 2014: 13-17
(Ann. WULS - SGGW, For. and Wood Technol. 86, 2014)

The change of mechanical properties of selected wood species after drying process under various conditions

JACEK BARAŃSKI, MACIEJ WIERZBOWSKI, ALEKSANDRA KONOPKA
Department of Energy and Industrial Apparatus, Faculty of Mechanical Engineering,
Gdańsk University of Technology, Poland

Abstract: *The result of mechanical properties change of selected wood species after drying process under various parameters 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. The global elasticity modulus and bending strength for steam dried, air-steam mixture dried and air dried samples as reference were measured. It allowed to reveal the effect of wood stream, air-steam mixture and their temperature on mechanical properties of wood. It has been recognized that steam and air-steam mixture drying cause of the mechanical properties changes of analyzed wood species.*

Keywords: wood drying, high-temperature drying, wood properties

INTRODUCTION

In the process of manufacturing timber, drying is the single most costly step in terms of energy consumption and time. Reducing energy wastage and processing times are two 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 kiln strongly interact with the heat and mass transport in the wood.

High temperature drying of wood is defined as a method of drying in the environment where the temperature is equal or higher than 100^{o}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] and need to specific management of the drying process.

MATERIALS

The experiments of drying process were conducted in the experimental kiln of 0.55 m^3 load capacity. The heat was supplied, thanks to hot flue gas generated in combustion chamber, heat exchanger placed in kiln. The heat exchanger and electric steam generator allowed to keep constant respectively temperature and huminidity inside kiln. Steam circulation inside the kiln was forced by circulation of 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 temperature inside kiln was set to 80^{o}C and 110^{o}C.

The system, which controls drying process, is located outside the kiln. It contains 4 thermocouples to measure respectively 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 content and 1 sensor to measure huminidity 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. Samples from a wood beam length of 4.5 m were cut with 70 mm × 70 mm × 1500 mm dimensions, Fig. 1. Before experiments high, width and length and moisture content of samples were measured.

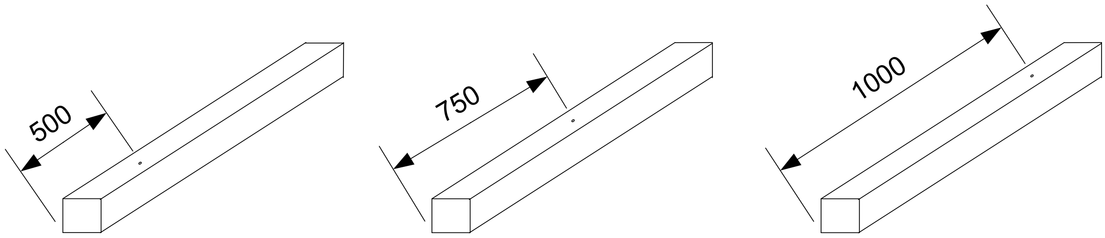

Fig. 1. The view of sample's place for moisture measurement.

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 [%]
Pine air dried	1	50.1
	2	50.4
	3	37.0
	4	31.8
	5	34.2
Pine high temperature dried (80^{o}C)	1	51.2
	2	49.6
	3	48.7
	4	34.0
	5	56.7
Pine high temperature dried (110^{o}C)	1	46.4
	2	46.5
	3	42.0
	4	33.9
	5	34.5

Samples		Average moisture content [%]
Beech air dried	1	74.3
	2	80.1
	3	87.3
	4	86.4
	5	76.9
Beech high temperature dried (80^{o}C)	1	70.6
	2	76.9
	3	87.1
	4	83.7
	5	79.8
Beech high temperature dried (110^{o}C)	1	76.5
	2	75.8
	3	86.2
	4	84.0
	5	79.2

All samples were dried in three ways: conventional (air) at 25^{o}C and accelerated respectively air-steam mixture at 80^{o}C and steam at 110^{o}C using an automatic control system. After drying process, the samples were checked, e. g. all dimensions and moisture content in five places. To measure moisture content hygrometer type WRD100 of Tanel Company was used, which is based on inductive method.

RESULTS

After drying process, the tests of global elasticity modulus and bending strength for air-steam mixture dried and steam dried samples and air dried 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 elasticity modulus, when bending, was conducted according to PN-EN 408:2004 as presented in Fig. 2.

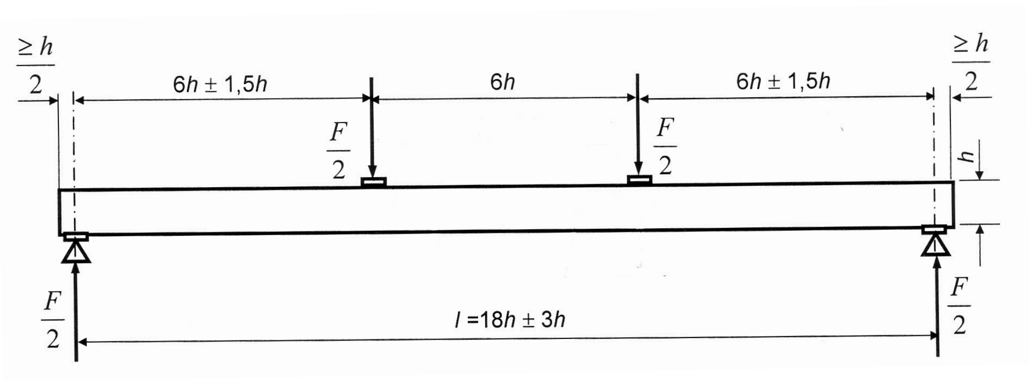

Fig. 2. Scheme of static test according to PN-EN 408:2004.

For experiments strength machine Tiratest 2030 was applied.

In Table 2 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 2. 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 modulus [N/mm^2]
Pine dried at 110^{o}C	12418.93	39.50	10735.74
Pine dried at 80^{o}C	13802.51	41.14	11315.31
Pine conventional air dried	12768.47	40.25	11550.52
Beech dried at 110^{o}C	16639,35	66,45	12632,53
Beech dried at 80^{o}C	18683,70	75,61	13546,24
Beech conventional air dried	20002,17	70,57	12460,15

CONCLUSIONS

The strength bending of pine wood elements dried at 110^{o}C is 39.5 N/mm^2, for items with dried at 80^{o}C is 41.14 N/mm^2. The same parameter in the control elements is 40.25 N/mm^2. The global elasticity modulus for wood dried at 110^{o}C is 10735.74 N/mm^2, for items dried at 80^{o}C is 11315.31 N/mm^2 and for control elements is 11550.52 N/mm^2.

The strength bending of beech wood dried in 110^{o}C is 66.45 N/mm^2, and for elements dried in 80^{o}C is 75.61 N/mm^2. Control elements have bending strength equal to 70.57 N/mm^2. The global elasticity coefficient of wood dried at 110^{o}C is 12632.53 N/mm^2, while for elements dried at 80^{o}C is 13546.24 N/mm^2. The control elements have coefficient equal to 12460.15 N/mm^2.

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., STĄSIEK J.: „Gas-steam mixture wood dryling". 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.

Streszczenie: *Zmiana własności mechanicznych wybranych gatunków drewna po procesie suszenia przebiegającym w różnych warunkach.*
W artykule przedstawiono wpływ warunków procesu suszenia na zmiany własności mechanicznych wybranych gatunków drewna. W badaniach wykorzystano sosnę (Pinus sylvestris L.) i buk (Fagus silvatica L.) pochodzące z północnej części regionu Pomorza. Mierzone były następujące wielkości mechaniczne charakteryzujące drewno moduł elastyczności, wytrzymałość na zginanie i siła niszcząca materiału po suszeniu drewna z wykorzystaniem pary wodnej, mieszaniny powietrzno-parowej i powietrza. Umożliwiło to ukazanie wpływu wykorzystania pary wodnej, mieszaniny powietrzno-parowej oraz ich temperatury na mechaniczne właściwości drewna. Stwierdzono, że zastosowanie pary wodnej oraz mieszaniny powietrzno-parowej wpływa na zmiany właściwości mechanicznych wybranych gatunków drewna.

Corresponding author

Jacek Barański
Gdansk University of Technology
Faculty of Mechanical Engineering
Narutowicza 11/12
80-233, Gdańsk, Poland
e-mail: jbaransk@pg.gda.pl