Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 72, 2010: 95-98
(Ann. WULS-SGGW, For and Wood Technol. 72, 2010)

Selected mechanical properties of steam kiln–dried wood determined on the basis of cutting power

K. A. ORLOWSKI[1], M. A. WIERZBOWSKI[2]
[1]Department of Manufacturing Engineering and Automation, Mechanical Engineering Faculty, Gdansk University of Technology, Poland
[2]Heat Technology Department, Mechanical Engineering Faculty, Gdansk University of Technology, Poland
Affiliation of Coauthor, Address, Country

Abstract: *Selected mechanical properties of steam kiln–dried wood determined on the basis of cutting power.* In this paper results of fracture toughness (specific work of fracture) and shear yield strength of steam kiln–dried wood determined simultaneously on the basis of cutting power measurement are presented. Wood species, namely oak (*Quercus robur* L.) and pine (*Pinus sylvestris* L.) from the northern part of Pomerania region in Poland, were subject of steam kiln–drying process in a laboratory kiln, specially designed and manufactured for the Gdansk University of Technology. It has been recognized that steam wood drying causes a decrease of the mechanical properties of the wood such as: fracture toughness and shear yield strength. Those mechanical properties were determined on the basis of the modern fracture mechanics.

Keywords: steam kiln-drying, wood, fracture toughness, shear yield strength, cutting power

INTRODUCTION

In the lumber manufacturing process, drying is one of the most costly consuming operation in terms of energy and time. Reduction of the energy consumption and drying processing time are currently two important objectives of timber industry. Drying in superheated steam is economically justified because of the shorter processing time and reduced energy consumption in comparison to drying in hot air. Evaporation of free water does not change wood shape and main dimensions during process of wood drying. With the loss of water evaporation zone moves deeper into the wood. The proper conduct of the drying process allows faster extraction of water [1 Gard, 2 Wierzbowski et al.]. The drying process was conducted in the experimental kiln (0.55 m^3 load capacity), equipped with a control system, especially designed at the GUT. There are two chimneys at the top to control pressure and environment conditions inside the kiln. The test stand is also equipped with a heat exchanger, which is supplied by exhausting gases from a furnace, allowing spread water to evaporate on its surface. Generated steam, by the circulation fan, is distributed between dried wood piles. The kiln is powered by the heat from both a heat exchanger, supplied with exhaust gases from burner, and fan's engine. That kind of location allowed us to minimize energy losses outside the kiln.

The drying time in the kiln is significantly reduced, nevertheless, the wood colour is changed. Thus, this phenomenon can testify that also mechanical properties could be also varied. For that reason, the mechanical properties of wood samples before and after an accelerated drying process have to be estimated. Since, Patel et al. [3] claim that cutting tests could be used as a substitute for fracture tests, moreover, cutting forces may be employed to determine not only toughness but also shear yield strength for a range of solids, including metals, polymers, and wood [4 Atkins], it was decided to apply the methodology proposed by Orlowski & Atkins [5], and also described by Orlowski & Palubicki [6].

MATERIAL AND METHODS

Samples were dried in the experimental kiln, in which the drying process consists of three phases. In the first phase wood material temperature was increased up to 95°C with scheduled progress, and water is supplied to the kiln to maintain proper humidity inside the kiln. This phase was not a really drying phase. Temperature was measured and used by the control system to switch to the next phase. In the second phase wood was dried to the final MC. After the drying phase timber was cooled down and conditioned at the programmed temperature. At this temperature MC-sensors can be used to confirm that the final MC was achieved. Those three phases comprised the drying schedule. The duration of those phases depends on the wood species and its thickness. For pine (*Pinus sylvestris* L.) the third phase was the longest while for oak (*Quercus robur* L.) the second phase lasted the longest. The oak samples were dried in three different patterns: air, steam with a manual control and steam with an automatic control (tab. 1). Pine lumber was dried only with an automatic control in cases of both prisms and boards.

In the sawing experiments the frame sawing machine applied PRW15M, which works with a kinematic system having an elliptical trajectory of the teeth movement. The driving system is dynamically balanced and it guarantees that no contact of the saw teeth with the kerf bottom occurs [7 Wasielewski and Orlowski]. Data of the machine tool: number of the saw frame strokes $n_F = 685$ rpm, stroke of the saw frame $H_F = 162$ mm, feed speed at two levels $v_f \approx 0.2$ m min^{-1} and $v_f \approx 1.0$ m min^{-1}, $m = 5$ number of saws in the gang, and average cutting speed $v_c = 3.69$ m s^{-1}. Data of saw blades with stellite tipped teeth which were employed in the tests: overall set (kerf) $S_t = 2$ mm, saw blade thickness $s = 0.9$ mm, a free length of the saw blade $L_0 = 318$ mm, blade width $b = 30$ mm, tooth pitch $P = 13$ mm, tool side rake angle $\gamma_f = 9°$, tool side clearance angle $\alpha_f = 14°$. Blocks and lumber (a set of 3 pieces) stacks made of pine (*Pinus sylvestris* L.) of $H_p = 70$ mm in height, with MC as in tab. 1 were cut. Prisms made of oak (*Quercus robur* L.) of $H_p = 70$ mm in height, with MC as in tab. 1 were sawed. The above mentioned data was the set of input values and the average value of the cutting power $\overline{P}_c$ was the output value. The mean value of total power $\overline{P}_{cT}$ and the idling power $\overline{P}_i$ of the main driving system were measured with a power transducer. The latter was determined directly before each cutting test. In computation of fracture toughness (specific work of fracture) and shear yield strength it was assumed that in the case of oak friction coefficient is equal to $\mu = 0.8$ and for pine $\mu = 0.6$.

Table 1. Drying patterns, initial and final MC for oak and pine samples

Type of wood and drying pattern	Drying time	Initial MC [%]	Final MC in kiln [%]	Final MC before sawing [%]	Comments
Oak / air	Appr. 3 months	58	-	9.7	
Oak / system control	4 weeks	58	13	10.2	Water nozzles directed on wood
Oak / manual control	31 hours	47	7	6.8	Water nozzles directed on exchanger
Pine / air	Appr. 2 month	25	-	6.5–9.8	
Pine prism / system control	58 hours	24	13	9.5–10.3	Water nozzles directed on exchanger
Pine board / system control	72 hours	25	12	7.2–9.4	Water nozzles directed on exchanger

RESULTS AND DISCUSSION

Figure 1 shows the comparison of fracture toughness *R* of pine and oak for both methods of drying: natural and accelerated in the kiln. For both species it is observed a decrease in fracture toughness as a result of accelerated drying.

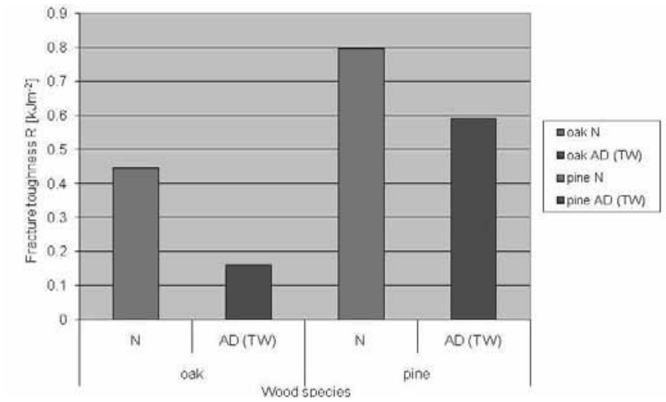

Fig. 1. Comparison of fracture toughness *R* of oak and pine, where: N – natural drying in air, AD – accelerated drying in the kiln

The comparison of shear yield strength of pine and oak for both methods of drying: natural and accelerated in the kiln is presented in fig. 2. For both species it is observed a decrease in shear yield strength caused by the accelerated drying.

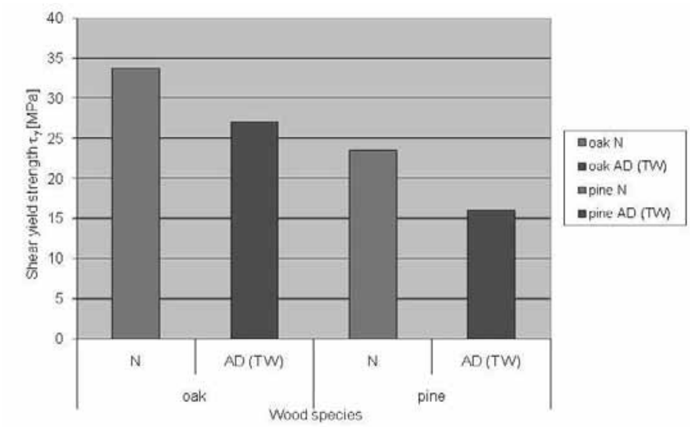

Fig. 2. Comparison of shear yield strength of pine and oak for both methods of drying: natural (N) and accelerated (AD) in the kiln

CONCLUSIONS

Although the sawing process is not a pure example of orthogonal cutting, the application of the results obtained by experimental cutting allowed us to determine toughness (specific work of fracture) and shear yield strength of the sawn wood. Obtained results revealed that accelerated drying of pine and oak conducted in the experimental kiln, according to the drying patterns as is shown in tab. 1, caused a decrease of wood mechanical properties such as fracture toughness and shear yield strength.

REFERENCES

1. W.F. Gard, High temperature drying on industrial scale. 1st Workshop "State of the art for kiln drying": Advances in drying of wood, Edinburgh, 1999.
2. M. WIERZBOWSKI, J. BARAŃSKI, J. STĄSIEK, Gas-steam mixture wood drying. In proc. of: 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 , 2009.
3. Y. Patel, B.R.K. Blackman, J.G. Williams, J.G., Measuring fracture toughness from machining tests. Proc. IMechE Vol. 223 Part C: J. Mechanical Engineering Science, 2009, pp 2861–2869.
4. A.G. Atkins, Toughness and cutting: a new way of simultaneously determining ductile fracture toughness and strength. Engineering Fracture Mechanics, Vol 72, 2005, pp 849–860.
5. K.A. Orlowski, A. Atkins, Determination of the cutting power of the sawing process using both preliminary sawing data and modern fracture mechanics. In: Proceedings of the Third International Symposium on Wood Machining. Fracture Mechanics and Micromechanics of Wood and Wood Composites with regard to Wood Machining, 21–23 May, Lausanne, Switzerland. Eds. Navi P., Guidoum A. Presses Polytechniques et Universitaires Romandes, Lausanne. 2007, pp 171–174.
6. K.A. Orlowski, B. Pałubicki, Recent progress in research on the cutting process of wood. A review COST Action E35 2004–2008: Wood machining – micromechanics and fracture". Holzforschung, Vol 63, pp181–185.
7. R. Wasielewski, K. Orlowski, Hybrid dynamically balanced saw frame drive. Holz als Roh- und Werkstoff, Vol 60, 2002, pp 202–206.

Streszczenie: *Określanie wybranych właściwości mechanicznych drewna suszonego z użyciem pary wodnej na podstawie mocy skrawania.* W niniejszym artykule przedstawiono wyniki wiązkości oraz naprężeń granicznych przy ścinaniu drewna suszonego z użyciem pary wodnej na podstawie zmierzonych wartości mocy skrawania. Badaniom poddawano próbki dębowe oraz sosnowe pochodzące z północnych regionów Pomorza. Wykazano, że przyspieszone suszenie drewna z użyciem pary wywołuje obniżenie badanych właściwości mechanicznych, które wyznaczano z wykorzystaniem współczesnej mechaniki pękania.

Corresponding author:
Gdansk University of Technology, Faculty of Mechanical Engineering, Department of Manufacturing Engineering and Automation, Narutowicza 11/12, 80-233 Gdansk, Poland
E-mail address: korlowsk@pg.gda.pl (Kazimierz Orlowski)