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The influence of drying parameters on wood properties

JACEK BARAŃSKI[1], DANIEL CHUCHAŁA[2], KAZIMIERZ ORŁOWSKI[2], TOMASZ MUZIŃSKI[2]
[1]Department of Energy and Industrial Apparatus, [2] Department of Manufacturing Engineering and Automation, Faculty of Mechanical Engineering, Gdansk University of Technology, Poland

Abstract: *The influence of drying conditions on wood properties is presented. In the paper the classical approach was used to determine energetic effects (cutting forces and cutting power) of wood sawing process on the basis of the wood specific cutting resistance, material constant. Wood species, namely pine (Pinus sylvestris L.)* and *beech (Fagus silvatica L.) from the northern part of the Pomerania region in Poland, were subject for determination of wood cutting properties after drying process at various conditions using air at 25°C, air-steam mixture at 80°C and steam at 110°C*

Keywords: cutting power, fracture mechanics, wood drying

INTORDUCTION

Theoretical and experimental determination of values of cutting forces acting in the cutting process belongs to the basic and simultaneously the most developed field of mechanics of this process. A great number of theoretical works, which were improved and experimentally verified, have been devoted to this problem. In the classical approach, energetic effects (cutting forces and cutting power) of wood sawing process are generally calculated on the basis of the specific cutting resistance k_c (cutting force per unit area of cut), [1, 2, 3], which in the case of wood cutting is the function of the following factors: wood species, cutting direction angle (cutting edge position in relation to wood grains), moisture content, wood temperature, tooth geometry, tooth dullness, chip thickness and some others which are less important, [4, 5]. Many of those traditional models are empirical and based upon limited information employing blades having standard thickness kerfs. Moreover, for each type of sawing kinematics, different values of specific cutting resistance k_c have to be applied, [3, 5, 6]. On the other hand, cutting forces could be considered from a point of view of modern fracture mechanics, [7, 8, 9, 10, 11]. In the quoted works, modeling of wood cutting process has been described as models with continuous chip formation. On the other hand, [12, 13], have investigated the conditions of chip propagation or fracture in orthogonal oblique cutting of beech wood with the discontinuous chip formation process. In analyses of sawing processes in which the off cut formation by shear occurs, Atkins's ideas, [8], can also be applied, for example in the real sawing process on a sash gang saw, [14, 15, 16, 17].

MATERIAL AND EXAMINED SAWING MACIHNE DATA

Samples were dried in the experimental kiln, [18]. The duration of drying process depended on the wood species. Predictions of cutting powers have been made for the sawing process on the sash gang saw PRW15M, Fig. 1, whereby three cutting edges of each tooth were in contact with the work piece and taken part in sawing. The process was conducted in a narrow slit.

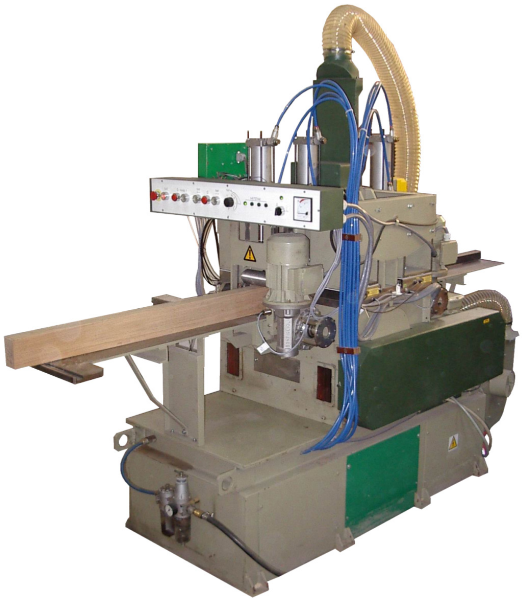

Figure 1. Narrow-kerf sash gang saw PRW15M.

The frame sawing machine PRW15M 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, [19]. Specifications 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 and $v_f \approx$ 1.3 m/min, m = 5 number of saws in the gang, and average cutting speed v_c = 3.69 m/s. Data of saw blades with stellite tipped teeth which were employed in the tests: overall set (theoretical kerf) S_t = 2 mm, saw blade thickness s = 0.9 mm, a free length of the saw blade L_0 = 318 mm, saw blade tension stresses σ_N = 300 MPa, blade width b = 30 mm, tooth pitch P = 13 mm, tool side rake angle $\gamma_f = 9^o$, tool side clearance angle $\alpha_f = 14^o$. Prisms made of pine (Pinus sylvestris L.) and beech (Fagus silvatica L.) of H_p = 70 mm in height, with MC, [19] were sawn. 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 $\overline{P}_i$ was determined directly before each cutting test.

The average value of the cutting power was calculated as the difference of the mean total power and the idling power of the main driving system according to:

$$\overline{P}_c = \overline{P}_{cT} - \overline{P}_i \tag{1}$$

After the cutting test each wood moisture content measurements were performed. To moisture measurements the moisture meter WRD-100 with measuring range of moisture content from 6 to 100 % and the accuracy of ± 1.5 % was used.

The samples in the form of prisms of wood: pine wood (Pinus sylvestris L.) and beech (Fagus silvatica L.) of depth of cut equal to H_p derived from the northern part of Pomerania region in Poland were cut. The sample was prepared in that way that in each case to have so called twin samples. Wooden prisms were divided over the length of 3 parts, and then the first of those were dried in open air (ambient temperature approx. 25°C), the second were dried under accelerated conditions in experimental kiln, at 80°C, and the third were dried in the experimental kiln at temperature 110°C. For each type of the test each portion of wood dried in the given conditions consisted of 8 - 9 samples were used for cutting experiments.

The samples were cut with two feed speeds, low (about 0.2 m/min) and higher (approximately 1.3 m/min) always adjustable after each wood element was cut. Computations were carried out in each case for one saw blade according to the procedure descirebed in details in the works [14, 15]. The significance analyses were done with the Fisher test for a significance coefficient value equal to $\alpha = 0.05$ [1].

RESULTS

In the following subchapters the results of cutting force and shear yield strength and will be presented respectively for pine and beech. These two wood species were dried in air at 25°C and in the experimental drying kiln using air-steam mixture at 80°C and steam at 110°C.

Cutting force for pine wood after drying process

Fig. 2 shows the cutting power per one saw blade during pine wood cutting dried respectively in the air, using air-steam mixture and steam.

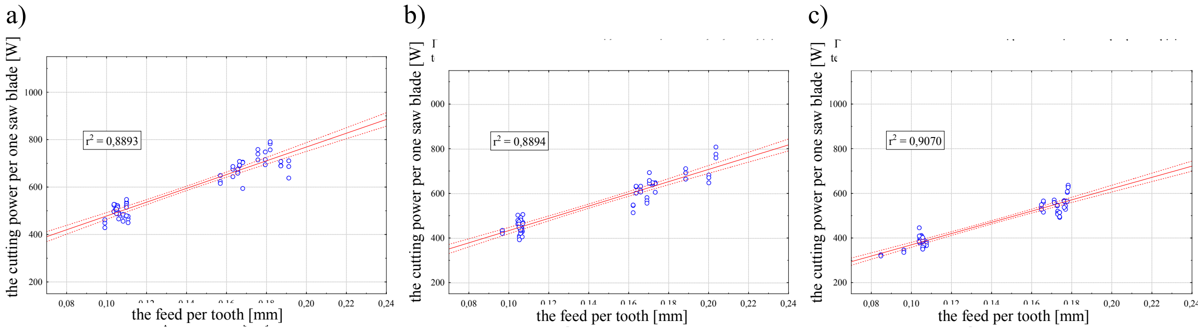

Figure 2. The cutting power per one saw blade as a function of the feed per tooth during pine wood cutting: a) air drying at 25°C, b) air-steam mixture drying at 80°C, c) steam drying at 110°C.

The cutting power per one saw blade during pine wood cutting is highest for material dried in air and decreases after drying process respectively using air-steam mixture at 80°C and steam at 110°C.

Shear yield strength for pine wood after drying process

The average values of shear yield strength in the shear zone of pine wood, with dispersions, for pine wood dried under different conditions are shown in Fig. 3.

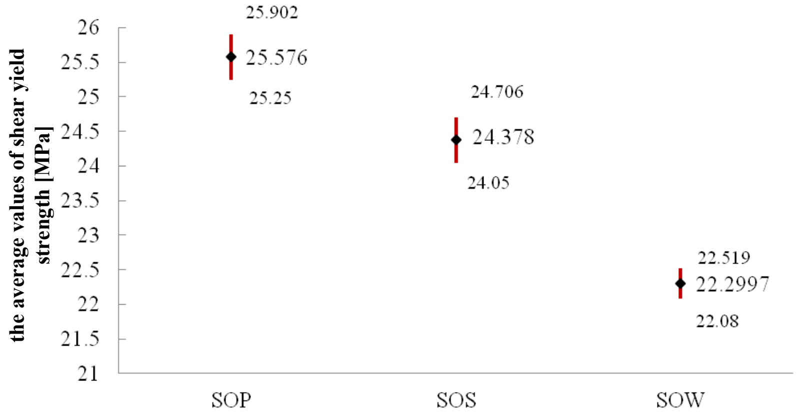

Figure. 3. The average values of shear yield strength in the shear zone of pine wood with dispersions: SOP - air drying at 25°C, SOS - air-steam mixture drying at 80°C, SOW - steam drying at 110°C.

In each cases of drying, compared with drying in air for the pine wood there is a statistically significant decrease in the value of shear yield strength in the shear zone.

Cutting power for beech wood after drying process

In Fig. 4 the cutting power per one saw blade during beech wood cutting dried respectively in the air, using air-steam mixture and steam is presented.

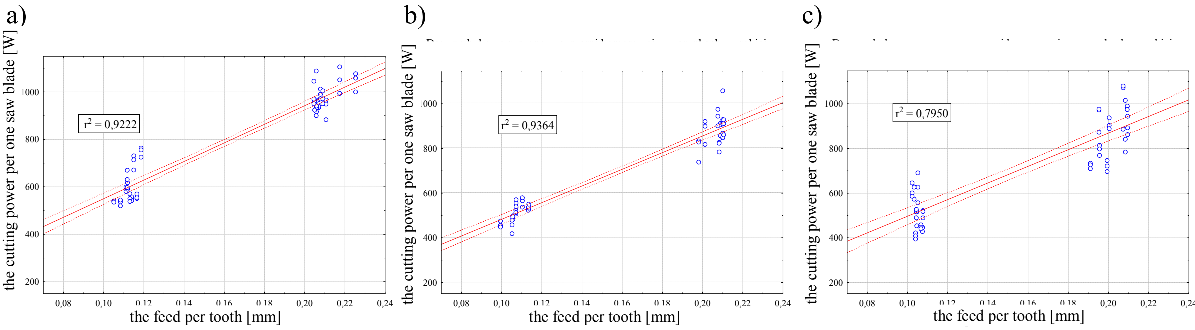

Figure 4. The cutting power per one saw blade as a function of the feed per tooth during beech wood cutting: a) air drying at 25°C, b) air-steam mixture drying at 80°C, c) steam drying at 110°C.

For the beech wood the cutting power is highest for material dried in air and lower for wood after drying process using air-steam mixture at 80°C and steam at 110°C.

Shear yield strength

The average values of shear yield strength in the shear zone of beech wood with dispersions dried under different conditions are shown in Fig. 5. In each cases of drying, compared with drying in the air, there has been observed a decrease in the value of shear yield strength in the shear zone for samples dried at elevated temperatures. However, between the medium values of shear yield strength in shear zone for drying conditions of investigated beech wood, respectively below and above 100°C, statistically significant differences weren't observed.

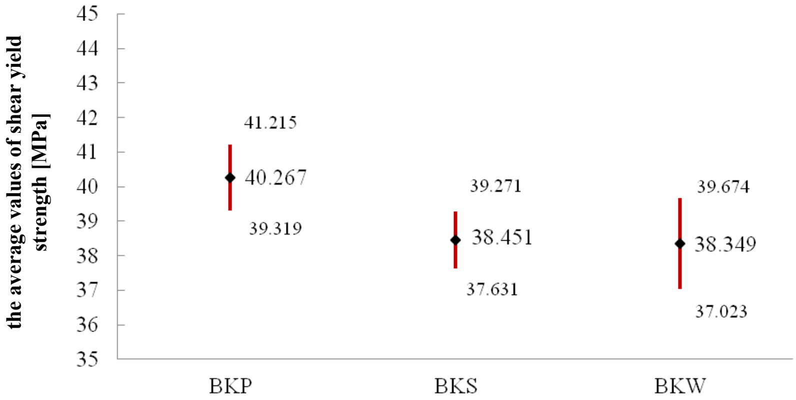

Figure. 5. The average values of shear yield strength in shear zone of beech wood with dispersions: BKP - air drying at 25°C, BKS - air-steam mixture drying at 80°C, BKW - steam drying at 110°C.

CONCLUSIONS

The cutting power per one saw blade during pine wood cutting is highest for material dried in air and decreases after drying process respectively using air-steam mixture at 80°C and steam at 110°C. For beech wood the cutting power is highest for material dried in air and lower for wood after drying process using air-steam mixture at 80°C and steam at 110°C.

The average value of shear yield strength in the shear zone of pine wood is highest for pine wood dried in air and significantly decreases after drying at higher temperatures. In turn, the average value of shear yield strength in the shear zone of beech wood slightly decreases for samples dried at elevated temperatures.

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Streszczenie: *Wpływ parametrów suszenia na właściwości drewna*
W artykule przedstawiono wpływ parametrów suszenia na własności skrawalnościowe drewna. W badaniach wykorzystano sosnę (Pinus sylvestris L.) i buk (Fagus silvatica L.) pochodzące z północnej części regionu Pomorza do określenia właściwości drewna, w postaci mocy skrawania oraz naprężeń tnących panujących w strefie skrawania, po procesie suszenia w różnych warunkach przy użyciu powietrza w 25^oC, mieszaniny powietrzno-parowej w 80^oC i pary wodnej w 110^oC.

Corresponding author

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