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INFLUENCE OF PARTICLEBOARDS PRODUCTION PARAMETERS ON WORK OF FRACTURE AND WORK OF CHIPS FORMATION DURING CUTTING

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ABSTRACT

The aim of the presented investigations was to analyse the influence of parameters of particleboards production on cutting properties of boards. Parameters that varied were temperature (180 and 220 °C) and pressure (2.5 and 4.0 MPa). Factors to define the cutting properties were: the work of fracture and the work of chip formation. Those factors describe the general work of cutting. Sharp and blunt tools were used. Cutting tests were carried out by using an equipped microtome technique.

The investigations show noticeable dependence between conditions of particleboards production and their cutting properties, especially for the work of fracture. The reduction of pressing temperature from 220 to 180°C gives about 25% decrease of energy demand to create a new surface. Studies of the energy of cutting are important not only for production energy demand aspect but also as the quality of the process and the tools wear process.

Key words: work of fracture, work of chip formation, particleboard, linear cutting.

INTRODUCTION

Published research concerning particleboards is usually focused on verifying the mechanical properties and describing its resistance on external factors variations as moisture or temperature. There is a need of study of particleboard's cutting properties.

Energetic aspects of particleboard cutting are presented by Wong and Schajer [4]. They observed significant relationship between chips' dimension in a particleboard and energy – consuming and path of a cutting. They noticed an increase of cutting forces and higher diversification of results with chips' size increase. In another publication [5] Wong affirms exact correlation of the moduli of rupture, the moduli of elasticity, the internal bond and the screw withdrawal resistance with average density of particleboard. He considered that in the case of typical particleboards there is a possibility to define internal and external layers density, basing on defined dependence between physical and mechanical properties of particleboards and conditions of the production. Andrews [1] affirms that the speed of board condensation and the density profile (crucial factors of board mechanical properties) are influenced by pressing parameters like temperature, pressure and speed of press closing. They observed that density diverged at transverse section is bigger with higher press pressure and speed of board condensation. In our former investigation [2] the work of fracture and the work of chip formation during laminated particleboard cutting were verified. A correlation between particleboard density and energy demand during cutting was found.

The aim of the presented investigations was to analyse the influence of parameters of particleboards production (temperature and pressure) on the cutting properties of boards. Factors that defined cutting properties were: work of fracture and work of chip formation.

EXPERIMENTAL DEVICES AND RESULTS INTERPRETATION

Total energy that is used to cut material is called the work of cutting. The work of cutting consists of the work of fracture and the work of chip formation. The work of fracture is necessary to create new surface and is independent from chip thickness [3]. The work of chip formation expresses the plastic deformation of removed material. Microtome technique was used to measure cutting forces. It is presented on Figure 1. This technique is based on registration of the cutting force (F_C) during cutting of a sample with length (l) and a variable height of cut layer (h) (Fig. 2). Forces were measured with two piezoelectric sensors, placed below the sample holder. Signals from those sensors, intensified via amplifier, were registered by computer. Signals from two sensors were registered separately and then summarised: $F_C = F_{C1} + F_{C2}$.

Fig. 1. Microtome (a) with tool and the sample holder view (b)

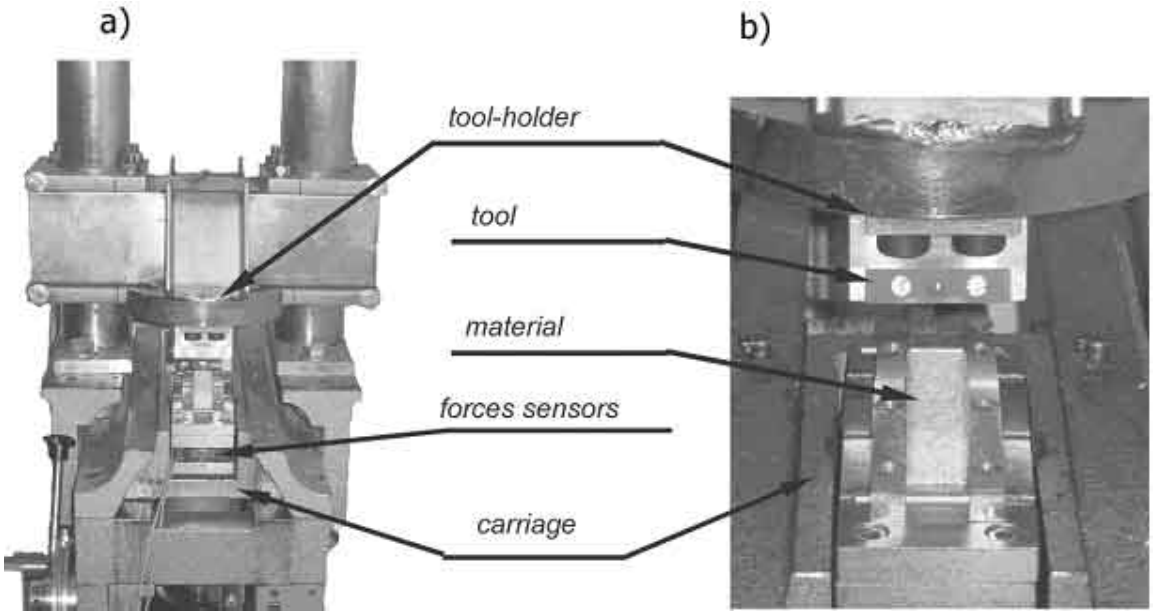
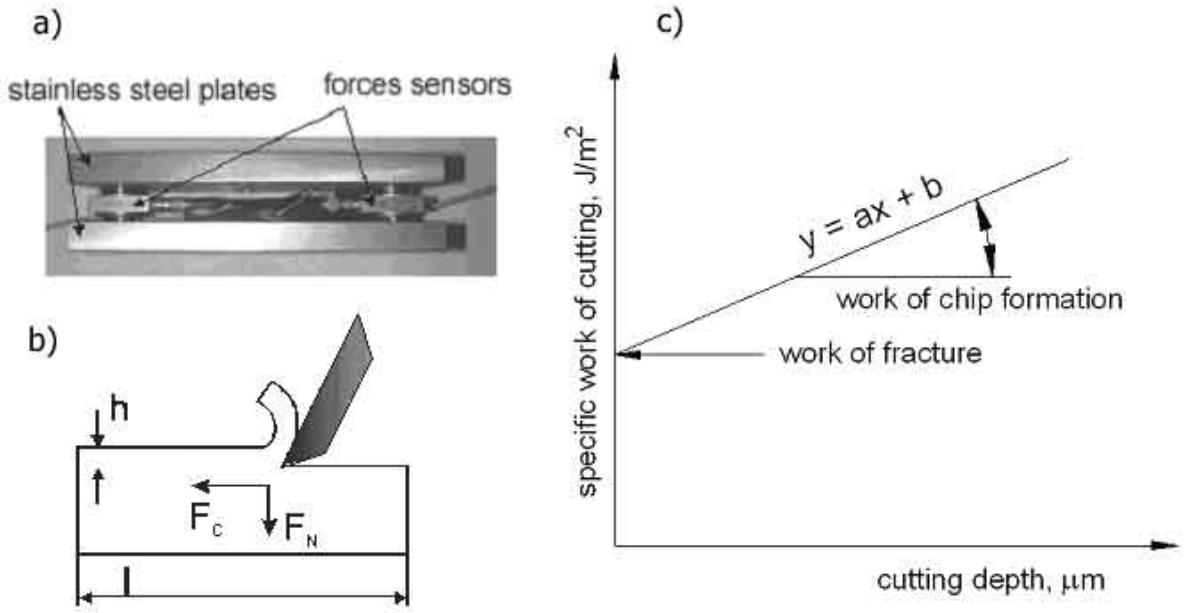


Fig. 2. Measure system with forces sensors (a), measured forces and their directions (b) and cutting work theory illustration (c)

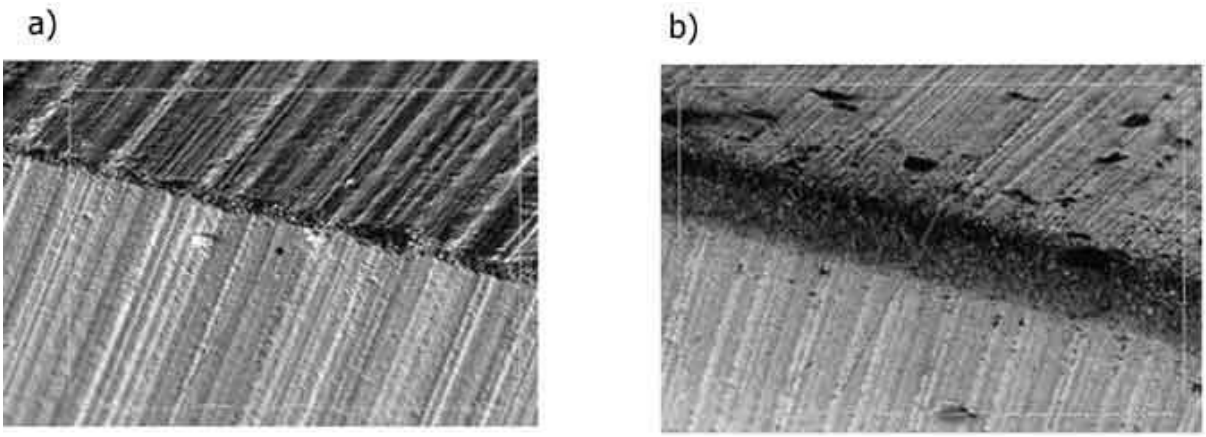


The cutting force and cutting way describe total work of cutting $E = F_C \cdot l$. That work, referred to surface of cut material, define work (energy) of cutting for surface unit (specific work of cutting) $E_A = E/A$ [J/m^2], were $A = l \cdot w$ (w – width of material). If the work of cutting relates to every cut layer, the thickness forms a linear function (y = ax + b), but does not cross 0,0 point at a Cartesian co–ordinate system. The component "b" of direct equations represents the work of fracture. The second part of energy is consumed for plastic deformation of removed material unit, so the line slope "a" represents the work for chip formation and its plastic deformation. Cutting material had width lower than the length of tool's cutting edge.

Cutting tools

Cutting tools were carbide inserts produced by Leitz, with the hook angle *beta* = 55°, fixed in a holder with the clearance angle *alfa*= 15°. There were two kinds of edges used in the experiment: new with the edge radius r = 2.5 micrometers and blunted with the edge radius r = 24.0 micrometers. The edge radius was measured with an electron microscope with 1000 times enlargement, and then a special method to compile photos taken at three different angles was used. Those photos have given a three–dimensional edge image. The size of blunt was selected basing on a former study and firma Leitz experience. Views of edges are presented on Figure 3. Average cutting speed was about 150 mm/s. Cutting length was 60 mm.

Fig. 3. Tools edges: sharp (a) and blunt (b)



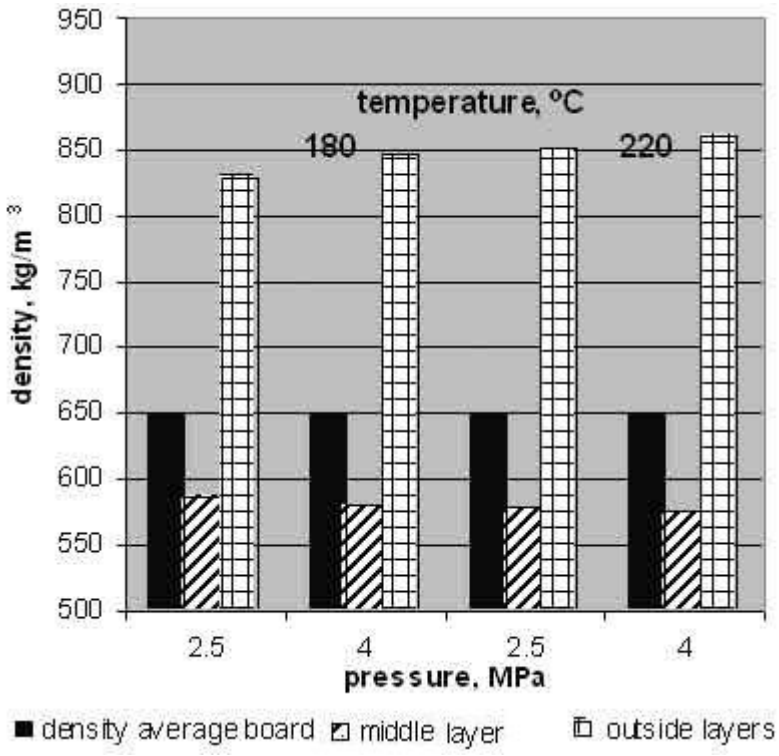
Material

During the investigation four different kinds of three–layer particleboards were used. They were fabricated with different parameters of pressure and temperature. Those parameters were changed because they are easy to control and modify in the industry. Production conditions of particleboards are shown in Table 1. Parameters of a press applied in particleboards industry are: pressure: 1.5-4.0 MPa and temperature: 150-230°C. The regular press time for all boards was 5 min. Urea-formaldehyde glue was used. During boards pressing with lower temperature (180°C) and higher pressure (4.0 MPa): overheat of board is slower and the temperature for full bind of resin is obtained after longer total time (Fig. 4). This permits stronger compression of outside plastic layers before their complete hardening. In the higher temperature (220°C) during particleboards' pressing the influence of the press pressure (2.5 or 4.0 MPa) on condensation of outside layers is decreased, because those layers hardened faster and then they are less susceptible to pressure effect. The higher temperature during board formation results in stronger compressing of the material for all applied pressing values.

Table 1. Conditions of particleboard production

Board number	Temperature, °C	Pressure, MPa
1	180	2.5
2		4
3	220	2.5
4		4

Fig. 4. Compilation of board's average densities and density of individual layers



RESULTS AND DISCUSSION

Sharp edge cutting results

The work of fracture and the work of chips formation do not show significant differences if the same temperature and different pressures are compared (Fig. 5, Table 2). If we consider results of cut tests at different values of temperature it can be noticed that the increase of pressing temperature from 180 to 220°C gives about 25% increase of energy demand to create a new surface on the one hand. On the other hand the work of chips

formation for 220°C is slightly lower than for 180°C, because the material is more brittle. As far as the work of cutting is concerned the temperature seems to be a superior factor, more important than the pressure. Results are in relation to those obtained for verification of density value.

Fig. 5. Sharp edge cutting results

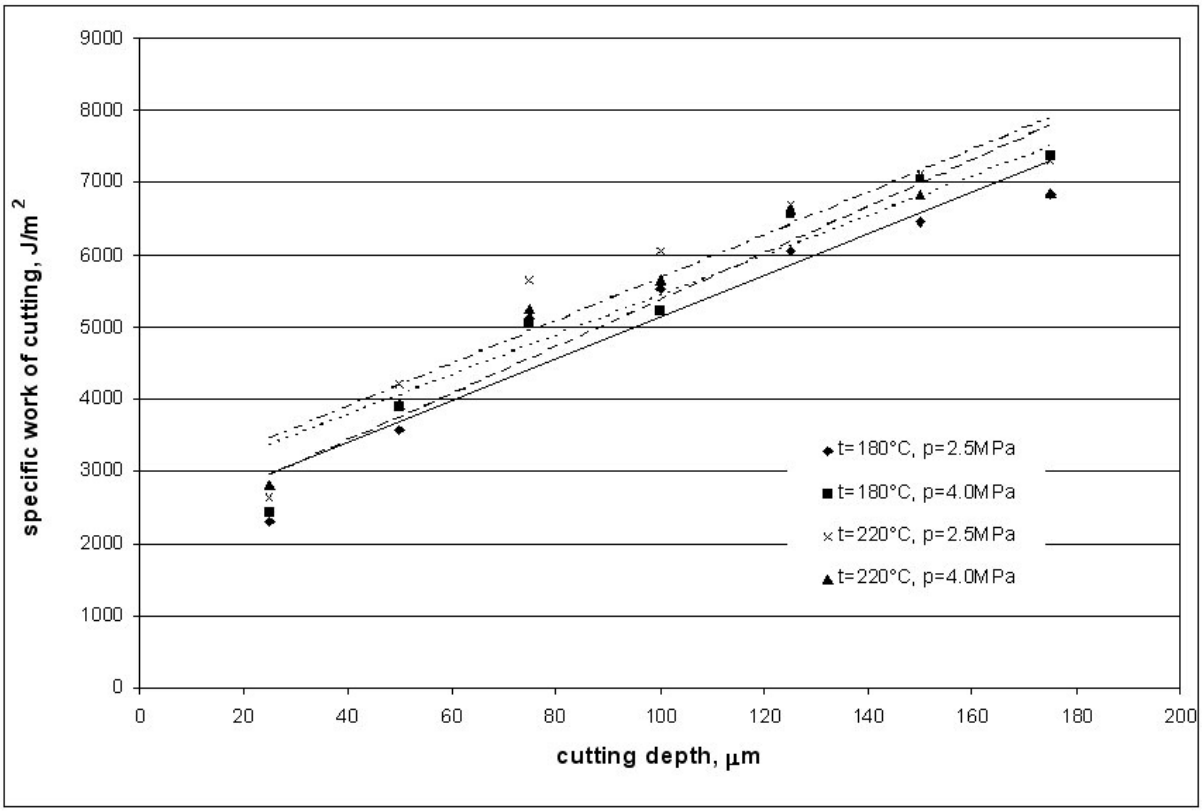


Table 2. Equations of linear regression for dependence of specific work of cutting versus the depth of cutting

	sharp edge		blunt edge	
	y = ax + b	R^2	y = ax + b	R^2
t=180°C, p=2.5MPa	y = 28.987x + 2230.5	0.9156	y = 33.127x + 3485.8	0.9384
t=180°C, p=4.0MPa	y = 32.329x + 2137.5	0.9558	y = 38.394x + 2025.8	0.9956
t=220°C, p=2.5MPa	y = 29.688x + 2700.0	0.8982	y = 32.273x + 2948.3	0.9056
t=220°C, p=4.0MPa	y = 27.567x + 2671.4	0.9113	y = 29.155x + 3103.8	0.9217

Blunt edge cutting results

Using blunt tools the work necessary to create a new surface is bigger than using sharp edge (Fig. 6, Table 2). This appears as a reaction of cut material on rounded edge. That is an effect of tool's pressure (Fig. 7). Particleboards are relatively brittle materials and crack in front of the tool's edge. For a blunt edge, this crack is created in a certain distance from the tool and its propagation is not "controlled" by the edge, as it is in case of the sharp edge. It is interesting, that the work of fracture depends less on the production conditions of particleboard than for sharp tools. It seems that we could use the same materials (fraction of chips, glue) to produce them because mechanical properties of the based material dominate over treatment conditions, as it is observed for the work of chips formation. Change of press temperature from 180 to 220°sC gives, like in the sharp edge case, decrease of the work of chips formation.

Fig. 6. Blunt edge cutting results

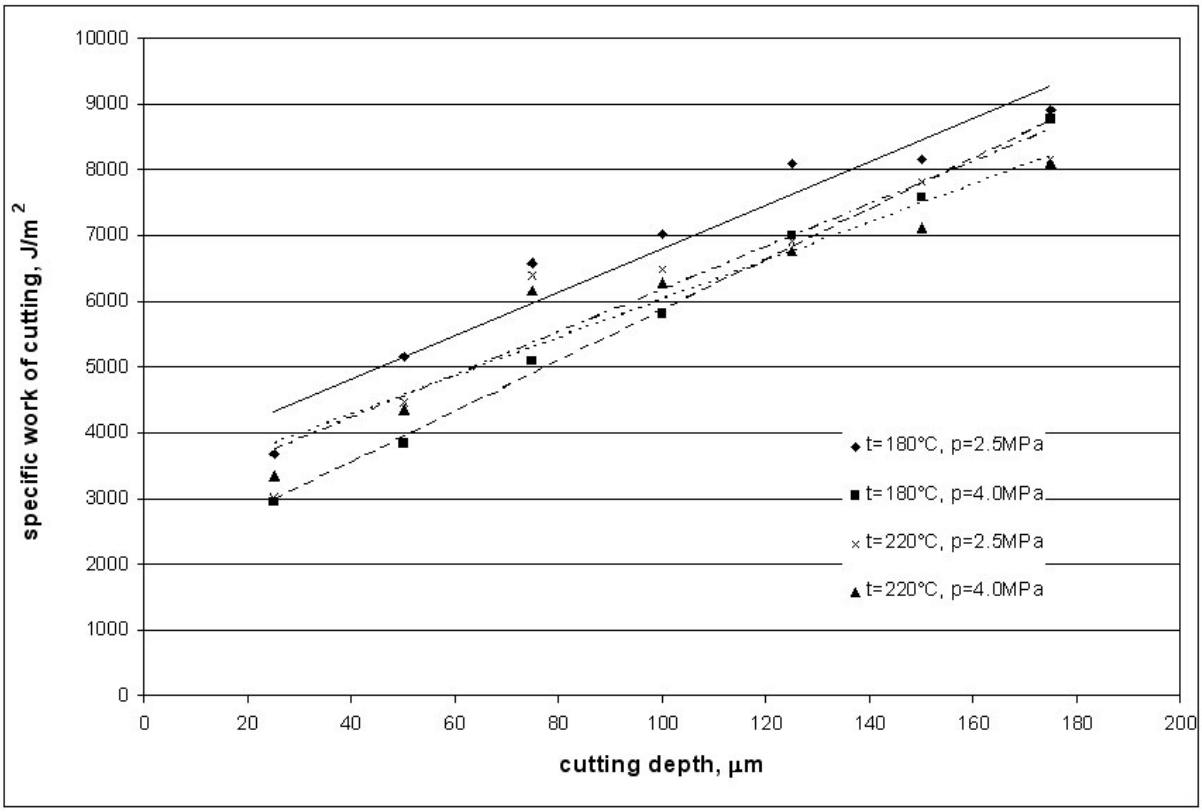
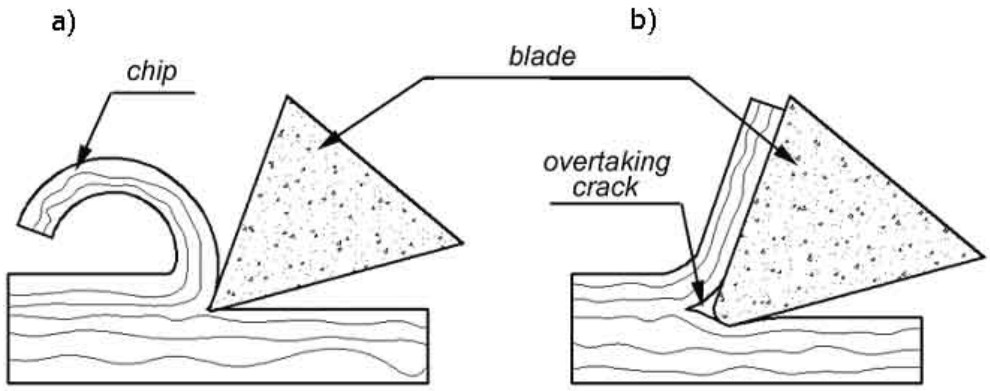


Fig. 7. Cutting with the sharp (a) and the blunt (b) edge



CONCLUSIONS

The press parameters in the production process influence to some extent the work of fracture and the work of chips formation. The temperature is the superior factor of the pressing process. Results of cut tests at different values of pressing temperature show that the rise of temperature from 180 to 220°C gives about 25% increase of energy demand to create a new surface. The tools blunting enlarges the work of fracture, but the influence of process parameters is less noticeable than for sharp tools. Reduction of the machining energy decreases direct costs connected with production. It diminishes tools wear and influence the quality as well. Additional economic effects are related with the use of milder conditions of particleboard production. In the next steps relations between mechanical properties of boards and cutting properties of boards will be considered.

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