Analysis of cutting forces from point of view fracture mechanics in quasi-orthogonal CNC milling and cutting by circular saw-blade. Part III

Luďka Hlásková, Zdeněk Kopecký, Jiří Kubeček, Jiří Procházka

INTRODUCTION

Wood has a property called hygroscopicity. This property is the cause of dimensional instability. To eliminate this disadvantage, wood modification is used. Thermal modification of wood is a process that changes the chemical structure of wood by temperatures from 150 °C to 260 °C and is aimed at improving its resistance to water and biological pests. When heated, chemical changes occur in the wood, which changes both the physical and mechanical properties.

The aim of research was to analyze the effect of different temperatures in the production of thermally modified wood on the cutting and feed force during circular saw blade cutting. Moreover, fracture parameters (fracture toughness and shear yield strength) were determined directly from the cutting tests.

MATERIAL AND METHODS

Modified spruce samples at 160 °C, 180 °C, 200 °C, 220 °C and unheated sample (REF) were used for the experiment. The thickness of all samples, ie the height of the cut was e = 20 mm. The cutting tests were carried out on a test rig for research via cutting with circular saw blades. The test rig simulated, as closely as possible, the conditions of a circular sawing machine in actual operation. The circular saw blade for longitudinal wood cutting with the straight, carbide-tipped teeth, were used for the experiment. The machine settings were as follows: optimum operating rotational speed = 3800 rpm; feed speed v_f varied between 2–22 m·min-1. This corresponded to changing of the mean uncut chip thickness hm and the feed per the tooth f_z. A series of 10 measurements were performed for each type of machined material and the present cutting conditions.

Fig. 1 Samples used in experiment

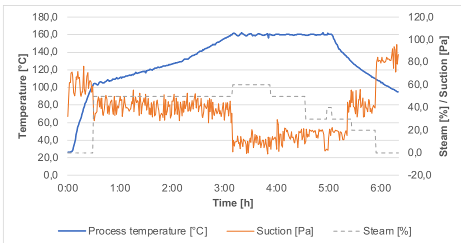

Fig. 2 Record of thermal modification

Fig. 3 Research device

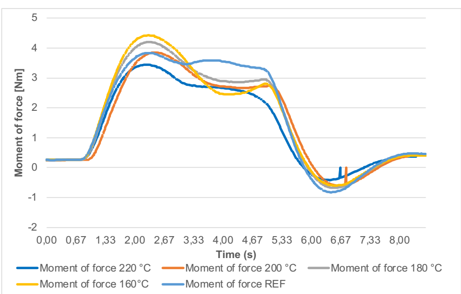

Fig. 4 Record of moment of force measurement

RESULTS

Cutting force was highest when machining the unheated wood (REF). We have also found that the higher the temperature during wood treatment, the lower the cutting force. The decrease in cutting force is due to the lower strength of heat-treated wood, which is associated with changes in the chemical structure of the wood components, weight and density loss, due to the increasing modification temperature.

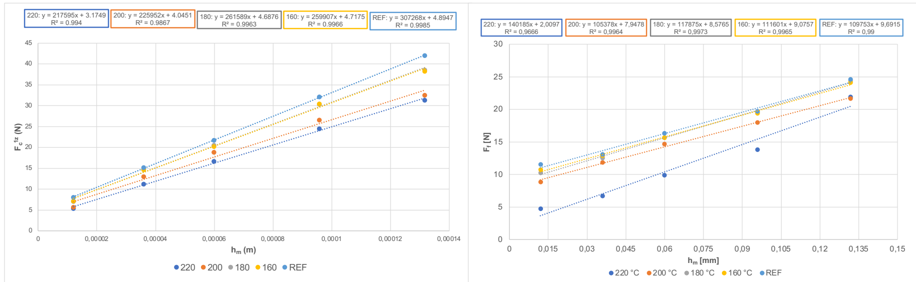

Fig. 5 Dependence of cutting force and feed force on uncut chip thickness

On the basis of the performed experiments, the main parameters of the newly designed model for thermally modified spruce wood were calculated.

Tab. 1 Comparison of fracture parameters

	μ [–]	β_μ [°]	ϕ [°]	γ [–]	Q_{shear} [–]	$\tau_{\gamma||\perp}$ [MPa] mean score ± SD	R [$J \cdot m^{-2}$] mean score ± SD
REF	0.264	14.798	37.600	2.068	0.797	32.9±0,543	1359.64±57,208
160	0.154	8.744	40.628	2.024	0.868	32.62±0,644	1310.42±79,349
180	0.158	8.962	40.519	2.024	0.865	31.29±0,613	1302.11±90,881
200	0.086	4.906	42.547	2.007	0.921	30.08±0,536	1123.64±56,797
220	0.402	21.904	44.048	1.480	0.716	28.93±0,487	881.92±71,852

Results show that the fracture toughness and shear yield strength of thermally modified wood is not only dependent on density but also on the modification temperature and its influence on the internal structure and the extent of cell wall degradation.

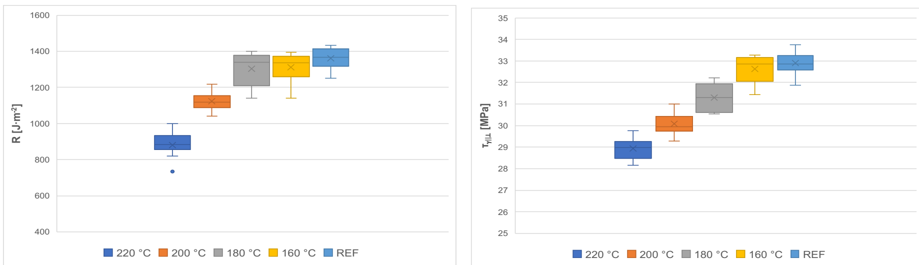

Fig. 6 Fracture toughness, shear yield strength

CONCLUSION

Basic relationships for calculating fracture characteristics of heat-treated spruce samples were derived from the cutting tests without the need to perform complex fracture tests. Thermally treated wood is characterized by increased hardness, fragility and susceptibility to crack formation, as well as reduced density, bending strength and shear strength. These properties significantly affect the size of the cutting force and feed force, as well as both parameters of the calculation model – fracture toughness $R_{||\perp}$ and shear yield strength $\tau_{\gamma||\perp}$.

ldf.mendelu.cz

MENDELU
Faculty of Forestry and Wood Technology