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Quality of profile milling on a cnc woodworking machine

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Abstract: *Quality of profile milling on a cnc woodworking machine*. The study presents investigations concerning the processing quality of profile elements manufactured in the CNC processing centre. Experiments were carried out on elements made of solid oakwood of a definite arrangement of annual rings using a cutterhead with two sets of blades: sharp and worn. In the course of investigations, production processing parameters were applied. Milling quality was determined by measurements and analyses of roughness parameters of the finished surfaces using for this purpose a profilometer with appropriate equipment. Varying relationships were found between the condition of the cutting edge and the roughness of the processed surface from the point of view of annual ring distribution of wood and place of measurement.

Keywords: profile milling, surface roughness, CNC processing centre.

INTRODUCTION

One of the factors affecting product quality is its final processing. Rectilinear or curvilinear processing is most commonly achieved by milling using, for this purpose, numerically controlled woodworking machines which allow quick and accurate execution of the process. The surface condition after milling on CNC woodworking machines must fulfil very high criteria resulting from continually increasing customer requirements as well as trends to shorten technological processes by eliminating troublesome technological operations, e.g. sanding. From practical point of view, a surface after milling should not require any other processing. High requirements regarding effective processing can only be achieved by the application of precisely manufactured tools accurately chucked in modern fixtures of working assemblies of woodworking machines. Accurate workmanship and geometry of the tool cutting edge exert a very strong influence on the quality of the processed surface, especially with regard to profile processing. Profile milling of solid wood characterised by a number of factors associated, in particular, with anisotropic wood structure is exceptionally challenging. Another important issue is connected with the wear of the cutting edge and its impact on surface quality (Pinkowski et al. 2009, Pohl 2005, Szymański et al. 2009). Variations in the setting of the cutting edge in relation to the processed material in the course of curvilinear profile milling exerts a strong influence on the surface quality in individual segments of the processed profile. Tool manufacturers continue to look for solutions which would make it possible to assess the condition of the surface after processing from the point of view of the cutting edge construction. The performed investigations should shed some light on some problems from this area.

The objective of this research project was to determine milling quality of solid oakwood profiled on a CNC woodworking machine from the point of view of selected factors regarding the cutting edge and processed material.

METHODS

Oakwood (Querqus robur L.) samples 397 mm long, 56 mm wide and 22 mm thick with oriented and repeatable arrangement of annual rings, were prepared and each of them was subjected to profile milling on their circumference on a CNC woodworking machine. Processing parameters are collated in Table 1.

Table 1. Processing parameters applied during milling on a CNC woodworking machine

Processing parameters	Value
Feed speed (v_f)	3 m·min^{-1}
Maximum machining diameter (D_{max})	85 mm
Minimum machining diameter (D_{min})	52 mm
rotational speed (n)	12000 min^{-1}
Number of machining cutting edges (z)	2
Material of knifes	HM

The tool used in the described experiments consisted of a mandrel profile cutterhead with a ProfilCut type of blade fixture. The processing was performed on a Weeke – Venture 3 processing centre using a tool chucked in an HSK milling fixture. The processed element was mounted using grips which allowed processing of narrow elements. The tool as well as the sample fixed on the processing centre is presented in Figure 1.

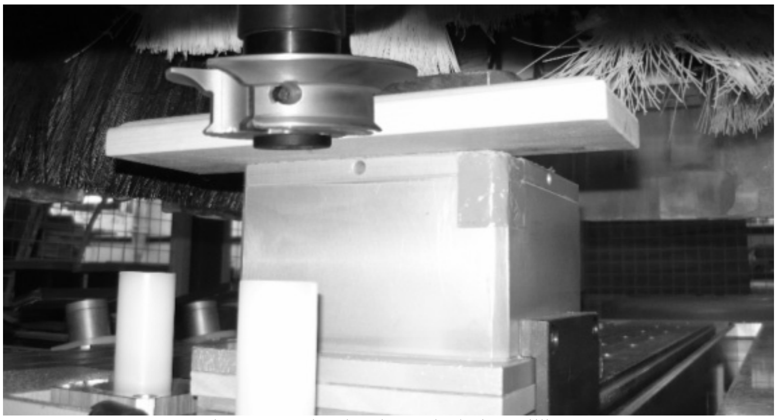


Fig. 1. Cutterhead and sample during milling.

Samples processed using a sharp and worn cutterheads were analysed. The maximum wear of the tool was achieved when the milling distance covered by the blade during processing of oakwood reached 400 running meters (rm). The adopted principal wear (technological) criterion of the cutting edge was the observed processing quality.

Samples subjected to roughness assessment were characterised by moisture content of 8%. Selected surface roughness parameters were examined for two sets of samples of definite arrangement of annual rings: tangential, semi-radial and radial. The first sample set was processed using sharp blades, while the second set – using worn blades. Figure 2 shows the view of samples prepared for investigations.

Measurements on each sample were performed in three characteristic places designated with letters: G, D and W (Fig. 3).

Surface profiles were registered using a Carl Zeiss ME-10 profilometer equipped in a measuring gauge with a rounding radius of 10 μm and the apex angle of 90^o. The feed velocity in the course of recording of the profile was set at 100 μm·s^{-1}. Data collected during recording were subjected to filtration in accordance with PN-EN ISO 13565-1:1999 and PN-EN ISO 11562:1998 standards. The applied cut-off length was 0.8 mm. The following parameters of wood surface roughness were adopted in accordance with the PN-84/D01005 standard: arithmetic average height Ra and the average peak to valley roughness Rz.

Annual ring distribution:

tangential semi-radial radial

A

B

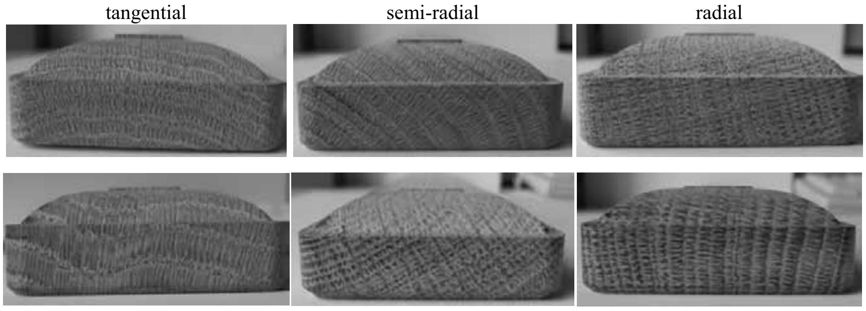


Fig. 2. Samples prepared for experiments: A – samples after processing with a sharp blade; B - samples after processing with a worn blade.

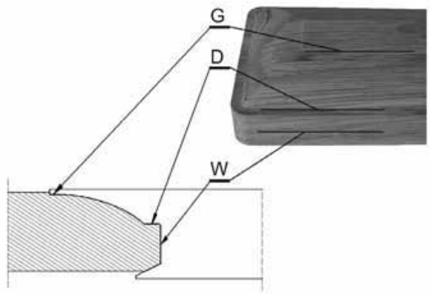


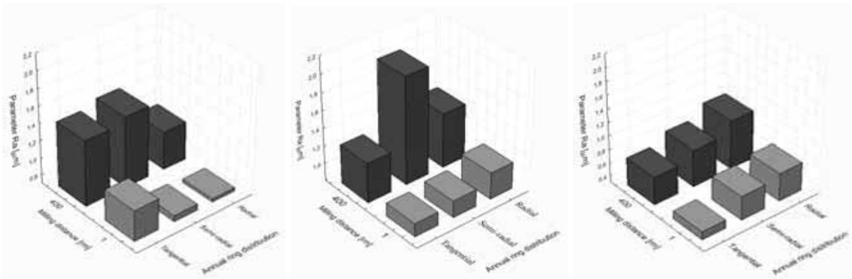
Fig. 3. Designation of measurement paths on examined samples

RESULTS

Values of the adopted roughness parameters are collated in Table 2, whereas Figures 4 and 5 present comparisons of surface roughness parameters of the examined samples depending on the distribution of annual rings and the milling distance.

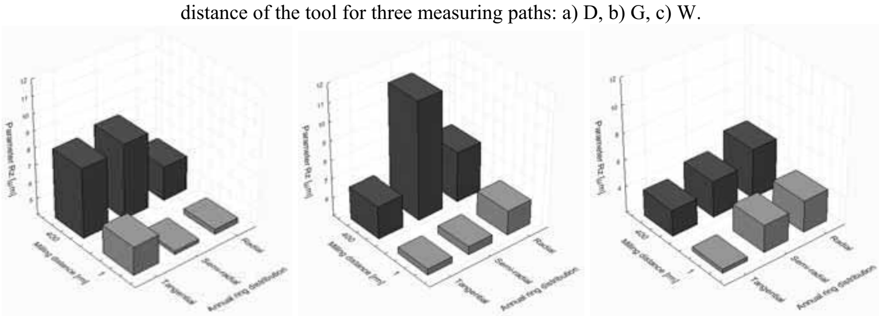
Table 2. List of the analysed surface roughness parameters

Annual ring distribution	Measurement place	Roughness parameter			
		Ra [μm]		Rz [μm]	
		Machining distance [rm]		Machining distance [rm]	
		1	400	1	400
tangential	G	0,95	1,25	5,33	6,75
	D	1,06	1,46	5,7	8,15
	W	0,42	0,72	2,31	3,97
semi-radial	G	0,99	2,02	5,44	11,31
	D	0,77	1,53	4,22	8,5
	W	0,66	0,85	4,05	4,71
radial	G	1,1	1,42	6,32	7,69
	D	0,74	1,14	4,31	6,01
	W	0,72	1,03	4,38	5,76



a) b) c)

Fig. 4. Arithmetic average height Ra of the profile depending on the distribution of annual rings and the milling distance of the tool for three measuring paths: a) D, b) G, c) W.



a) b) c)

Fig. 5. Average peak to valley roughness Rz of the profile unevenness depending on the distribution of annual rings and the milling distance of the tool for three measuring paths: a) D, b) G, c) W.

The analysis of surface roughness parameters presented in Figs. 4 and 5 make it possible to conclude that there was a clear increase in the values for the surface processed with the worn cutting edge in comparison with the surface processed with the sharp blade. For the Ra parameter, this increase ranged from 22% in the case of the radial system for the G measuring path to 50% in the case of the semi-radial system for G and D measuring paths. In the case of the Rz parameter, the increase ranged from 15% for the semi-radial system for the W measuring path to over 50% for the semi-radial system for G and D measuring paths.

The comparison of roughness parameters from the point of view of annual ring distribution as well as the choice of measuring paths failed to indicate unequivocally any interrelations.

The maximal oakwood milling distance for all the analysed annual ring arrangements amounting to 400 rm constituted the upper limit and, in some cases, exceeded it. It was the distance at which it was possible to accept the results of processing from the point of view of the occurrence of burns. Burns occurred both on straight sections as well as on corners. Figure 6 presents examples of burns.

The most conspicuous burns on straight sections were observed on samples with radial annual ring arrangement and the least visible – for the tangential ring arrangement. Corners changed colour as a result of burning irrespective of the distribution of annual rings.

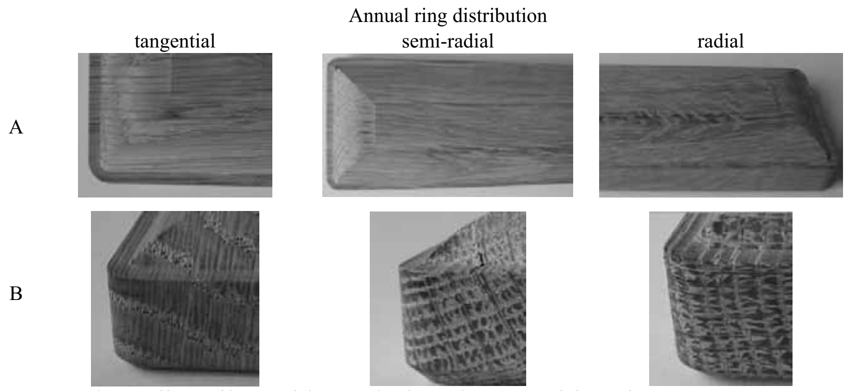


Fig. 6. Effects of burns of the examined samples: A – straight sections; B – corners

CONCLUSION

Profiles of oakwood surfaces milled on a CNC woodworking machine using a cutterhead with worn cutting edges showed a distinct increase of roughness parameters in comparison with surfaces processed with sharp blades. The increase for the Ra parameter ranged from 22% to 50% and for the Rz parameter – from 15% to 52%, depending on the annual ring distribution and location of the measurement.

Significant spreads of increased roughness of oakwood surfaces as well as the location of the determined wood burns indicate the necessity for the determination of a technologically optimal criterion of the cutting edge wear with reference to places of processing characterised by the most unfavourable processing results. Identification of such places, which requires further investigations, can provide important information about the construction and geometry of the cutting edge as well as about the selection of milling parameters.

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Streszczenie: *Jakość frezowania profilowego na obrabiarce CNC.* W pracy przedstawiono badania dotyczące jakości obróbki elementów profilowych wykonanych na centrum obróbkowym CNC. Badania przeprowadzono na elementach z drewna litego dębowego o określonym układzie słojów z wykorzystaniem głowicy frezowej z dwoma kompletami noży: ostrych i zużytych. W czasie badań zastosowano produkcyjne parametry obróbki. Jakość frezowania określano poprzez pomiar i analizę parametrów chropowatości obrobionych powierzchni, z wykorzystaniem profilografometru z odpowiednim oprzyrządowaniem. Stwierdzono zróżnicowane zależności pomiędzy stanem ostrza, a chropowatością obrobionej powierzchni, w ujęciu układu słojów drewna i miejsc lokalizacji pomiaru.

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