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INFLUENCE OF THE THICKNESS OF REMOVED LAYER ON THE QUALITY OF CREATED SURFACE WHEN MILLING OAK BLANKS ON THE CNC MACHINING CENTER

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Abstract

The article deals with the quality of oak blanks machined on the CNC machining center. It focuses on the effect of the thickness of removed layer on the quality of created surface, namely its indicator arithmetical mean deviation of the roughness profile Ra. The paper presents results of operating experiment, in which the edges of the oak blanks of thickness h = 25 mm were milling with end mill of diameter D = 16 mm fitted with a replaceable T10MG carbide blade. The experiment was performed on a 5 axis CNC machining center at tool speeds n = 20,000 rpm, feed speed $v_f = 1 \div 5$ *m.min*$^{-1}$ *and thickness of removed layer e = 1, 3 and 5 mm.*

The article states that, the arithmetical mean deviation of the roughness profile was in the range of Ra = 5.6 ÷ 7.1 μm. The analysis of the results points to the fact that, the impact of the thickness of removed layer and feed speed on the surface roughness was not demonstrated. As an explanation of the phenomenon, the article provides a comparison the thickness of the chips in the layer corresponding to the new surface depending on the technical and technological parameters of the process.

Key words: *CNC machining center, end mill with a replaceable carbide blade, quality of created surface, thickness of removed layer, feed speed, thickness of the chips.*

INTRODUCTION

The workpiece accuracy and the quality of a created surface can be regarded as an objective indicator of the quality of the created product. The workpiece accuracy presents the degree of approaching of the geometric values of the workpiece to the values set in the drawing, as the shape and dimensional accuracy is considered (*Kminiak, Banski and Chakho, 2017*).

An adequate accuracy is solved by CNC machining centers by the machine itself, therefore the quality of the worked out surface seems to be more important issue. The surface quality can be exactly defined by surface roughness parameters (*Siklienka et al. 2017*).

The surface shows some surface roughness during milling as well, such as microscopic changes (roughness) or macroscopic changes (waviness, grooves, elevations, partially drawn fibers). The occurrence of these changes (except waviness) on the workpiece surface is irregular (*Korkut, Diziroglu and Aytin, 2013*). The waviness consists of almost regular

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repetitive elevations and depressions of approximately the same shape and size (*Gündüz, Korkut and Korkut, 2008, Novák, Rousek and Kopecký, 2011*).

Roughness and waviness are, in fact, very small deviations from the desired shape, but they significantly affect the further processing of the workpiece, in particular its surface treatment (*Aydin and Colakoglu, 2005, Očkajová et al. 2016*).

Roughness and waviness depend on the kinematic conditions of cutting and are mainly influenced by the following factors:

- The way of separating chips, which depends not only on the method of machining, but also on the accuracy of a tool and its geometry.
- Cutting conditions (cutting speed, feed speed, thickness of the removed layer, etc.).
- Microgeometry (dulling the cutting edge of the tool).
- Physical and mechanical characteristics of machined material (its density, hardness and structure) (*Karagoz, Akyildiz and Isleyen, 2011*).

This article aims to analyze the influence of the thickness of removed layer and the feed speed on the quality of created surface when milling the oak blanks.

MATERIAL AND METHODS

Experimental samples:

In the experiment were used European oak (Quercus robur) blanks of dimensions h = 25 x w = 55 x l = 500 mm and the moisture WP 8 ± 1%.

Experimental machine:

Blanks were milled on 5 axes CNC machining center SCM Tech Z5 (*Fig. 1*) supplied by SCM–group, Rimini, Italy. Basic technical and technological parameters provided by the manufacturer are presented in *Tab. 1*.

Experimental tool:

In the experiment was used end mill KARNED 4451 of diameter D = 16 mm fitted with a replaceable T10MG carbide blade from the manufacturer Karned Tools Ltd., Prague, Czech Republic (*Fig. 2*). Basic technical and technological parameters provided by the manufacturer are presented in *Tab. 2*.

Fig. 1. CNC machining center SCM Tech Z5 (*SCM Group, 2017*).

Tab. 1. Technical and technological parameters of CNC machining center SCM Tech Z5 (*SCM Group, 2017*).

Technical parameters of CNC machining center SCM Tech Z5	
Useful desktop	x= 3,050 mm , y = 1,300 mm, z =300 mm
Speed X axis	0 ÷ 70 m.min^{-1}
Speed Y axis	0 ÷ 40 m.min^{-1}
Speed Z axis	0 ÷ 15 m.min^{-1}
Vector rate	0 ÷ 83 m.min^{-1}
Parameters of the main spindle	
electric spindle with HSK F63 connection	
Rotation axis C	640°
Rotation axis B	320°
Revolutions	600 ÷ 24,000 ot.min^{-1}
Power	11 kW 24,000 ot.min^{-1}
	7,5kW 10,000 ot.min^{-1}
Maximum tool diameter	D = 160 mm
	L = 180 mm

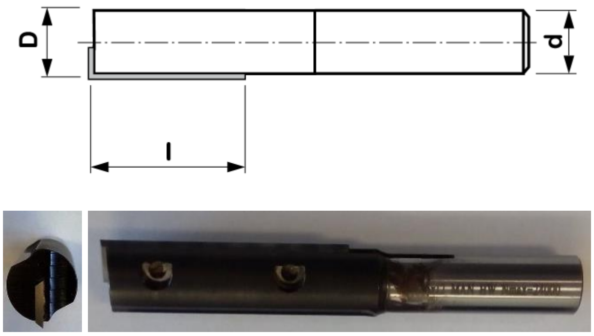

Fig. 2. End mill KARNED 4451 fitted with one replaceable carbide blade (D – cutting diameter, L – cutting length, d - diameter of the chucking shank)

Tab. 2. Technical and technological parameters of end mill KARNED 4451 fitted with one replaceable carbide blade (Karned Tools Ltd, 2017)

Miller	**Working diameter D [mm]**	**Working length l [mm]**	**Diameter of the chucking shank d [mm]**	**Dimensions of used razor blades L x š x h [mm]**	**Blades material**
KARNED 4451	16	49,5	12	49.5 x 9 x 1.5	**T10MG**

Classes of TIGRA	**ISO CODE**	**US CODE**	**Binder%**	**Hardness**		**Bending strength**	
				HV10	**HRA±0.2**	**N/mm^2**	**psi**
T10MG	K10–K40	C3+	10.0	1,65	92.3	3,6	522.000

Milling process:

A milling cutter was fitted into the hydraulic clamp SOBO. 302680291 GM 300 HSK 63F from Gühring KG, Albstadt, Germany. Oak blanks were placed in a CNC machining center so that the longer side was in the X-axis and the shorter side was in the Y-axis. Oak blanks were clamped during the milling by mechanical clampers VCMC-S4 145x145x50 12-80 from J. Schmalz GmbH, Glatten, Germany. The milling process was carried out at constant operation speed of cutter n = 20,000 min^{-1} and changing thickness of the removed layer e = 1/3/5 mm and changing feeding speed from v_f = 1 $m.min^{-1}$to v_f = 5 $m.min^{-1}$ (representing a maximum feeding speed recommended by the manufacturer of the tools).

Determination of surface roughness:

The surface roughness of the samples was measured with a laser profilometer LPM-4 (*Fig.3*) by the manufacturer Kvant Ltd, Bratislava, Slovak Republic. The profilometer uses a triangulation principle of laser profilometry. The image of the laser line is scanned at an angle by digital camera. Afterwards, an object profile in cross-section is evaluated from scanned image. Obtained data are mathematically filtered and there are set individual indicators of the primary profile, profile of waviness and profile of roughness (*Kminiak and Gaff, 2015*).

There was used a methodology by *Siklenka and Adamcova (2012)* for measuring of the surface roughness that fulfills the standard EN ISO 4287. Within each sample, there were realized measurements in three tracks, located in the middle of the sample, evenly located across the width of the sample (5/12.5/20 mm from the sample edge), track length was 60 mm and the track was oriented in the direction of displacement of the spindle in a milling process. Surface roughness was evaluated by using parameter of arithmetic mean deviation of roughness profile Ra.

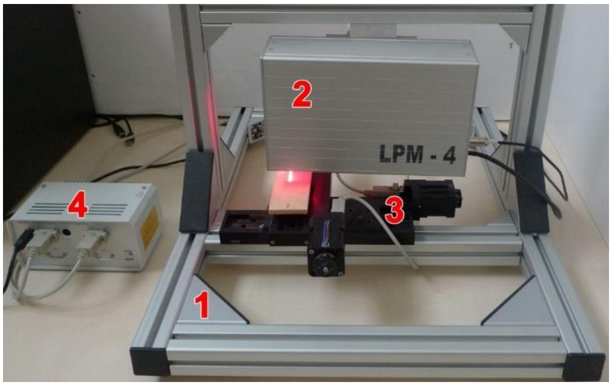

Fig. 3. Laser Profilometer LPM - 4 (1 - supporting structure allowing manual setting of working distance and fitting of profilometric head and trolley system, 2 - profilometric head, 3 - feed system of the XZ axis, 4 - control system of working desk shifts) (*Kminiak and Gaff 2015*)

RESULTS AND DISCUSSION

The roughness of the formed surface was monitored by arithmetical mean deviation of the roughness profile Ra. The obtained data were subjected to statistical analysis for the purpose to confirm or refute general assumptions about dependence of surface roughness on the parameters of the chopped layer under specific machining conditions on the CNC machining center. Among the arguments the validity of which we had in order to verify in the given conditions are:

- increasing the feed speed decrease the quality of the created surface,
- increasing the thickness of removal layer decrease the quality of the created surface.

Specific machining conditions on a CNC machining center result mainly from the tool diameter. Most of basic research in this area is based on the experiments performed on the vertical single spindle miller with a tool diameter D = 100÷120 mm. We use tools of a much smaller diameter in the CNC machining center, for example D = 10÷30 mm. The different tool diameter causes a different direction of the cutting forces in the cutting area, which should be reflected in the topography of the surface, especially at the roughness level.

The statistical evaluation of the data (*Tab. 3*) has shown that the feeding speed or thickness of removal layer not have a statistically significant effect on the quality of the created surface.

Tab.3. Multifactor analysis of the impact of the thickness of removal layer and the feed speed on the arithmetical mean deviation of the roughness profile.

	SS	Degr. of Freedom	MS	F	p
Intercept	10573,15	1	10573,15	4731,331	0,000000
thickness of removal layer	1,47	2	0,74	0,329	0,719803
feed speed	18,46	4	4,62	2,065	0,085805
thickness of removal layer*feed speed]	28,17	8	3,52	1,576	0,132360
Error	569,85	255	2,23		

Graphic representation of dependence of the arithmetical mean deviation of the roughness profile on the thickness of removal layer and the feed speed is shown in the graph in *Fig.4*.

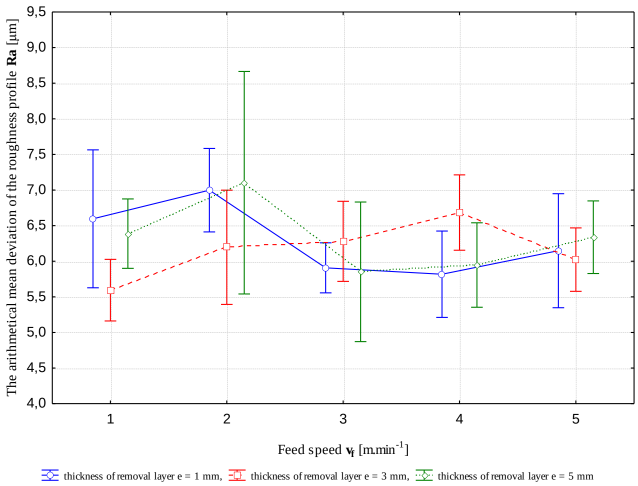

Fig.4. Influence of feed speed and thickness of removal layer on the arithmetical mean deviation of the roughness profile.

In graphical expression cannot be observed a significant trend that would confirm the dependence of roughness on the monitored parameters.

The arguments which we are trying to confirm, have their basis in the assumption that, the increasing nominal thickness of the chips causes the change in the force ratios at the place of separation of the chips and consequently deterioration of roughness as a result of microcracks.

Why this is not in our case, it can be justified as follows. Although the thickness of removal layer is increasing 1/3/5 mm, but the height of the layer in which the final surface is formed remains relatively small. The height of the layer in which the final surface is formed can be identified with the maximum heights of the primary profile. Although the thickness of removal layer increase, the average value of the maximum height of the waviness profile changes only slightly and its values are in the range of 0.21 ÷ 0.36 mm (*Fig.5*).

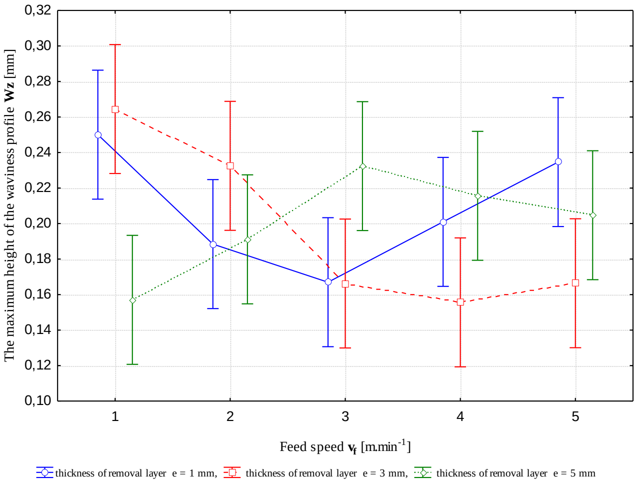

Fig.5. Influence of feed speed and thickness of removal layer on the maximum height of the waviness profile

Subsequently, the maximal chip thickness within the height of forming a final surface is in e range of 0.0084 to 0.047 mm. *Fig. 6* provides a comparison of the maximum thickness of the chips found in the height corresponding thickness of removal layer and height corresponding the layer in which the final surface is formed. As can be seen in the chart, the increase of the thickness of removal layer and feed speed do not cause significant change.

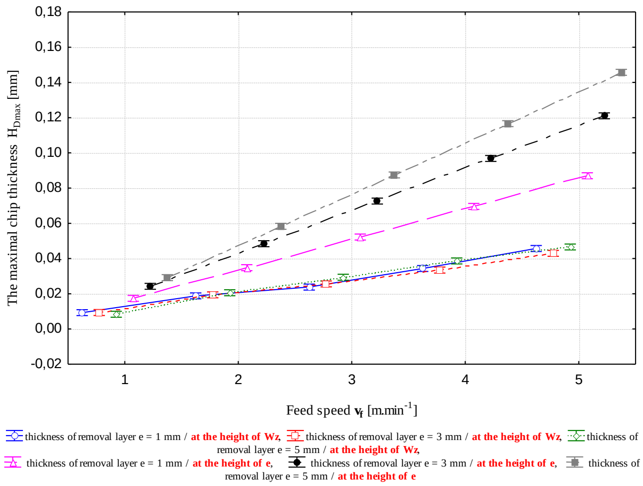

Fig. 6. Influence of feed speed and thickness of removal layer on the maximal chip thickness

CONCLUSION

When milling oak blanks with end mill fitted with one replaceable carbide blade on a CNC machining center, it is possible to achieve surface roughness at the level of 5.6 ÷ 7.1 μm.The influence of the feed speed as well as the thickness of removal layer on the surface roughness was not demonstrated.

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