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THE EFFECT OF THE CIRCULAR FEED ON THE SURFACE ROUGHNESS AND THE MACHINING TIME

Abstract. *The surface roughness is analysed in different feeds and turning procedures (rotational and conventional) in this paper. Cutting experiments were made on different cutting speeds and feed rates with 2 cutting tool with helical edge geometry and 1 traditional turning tool. The measured 2D surface roughness values were compared between the different cutting tools. The benefit of the circular feed application is showed by the decrease of roughness parameters and machining time.*

Keywords*: machining time; rotational turning; surface roughness.*

1. INTRODUCTION

The produced surface quality and the efficiency of the machining depends on the applied cutting procedure. Kundrák et al. showed in studying finishing procedures of bore machining that the same surface roughness can be achieved by various kinematic relations, however the machining time will be different depending on the procedure [1]. Varga et al. analysed the effect of burnishing after grinding [2], which leads to better surface topography, however the machining time will be consequently higher. Qehaja et al. studied the dry turning process [3], where they concluded that the feed rate has a high influence on the machining time and surface roughness. Niaki et al. analysed different tool grades and showed that the stability of the cutting edge also has a high impact on the generated surface. The application of the application of unconventional machining methods are shown in the work of Berenji et al. [4]. They determined that the application of different procedures can lead to better surface quality while also increasing the efficiency. An edge with helical geometry and a tangential circular feed are applied in rotational turning [5]. Therefore, the applied kinematics and edge geometry has a major effect on the surface quality and the efficiency. The aim of this paper is to analyse roughness values and the machining time in cutting of cylindrical surfaces with different kinematics and edge geometry (rotational and longitudinal turning).

2. EXPERIMENTAL CONDITIONS

In this study, the experimental work was carried out on a Perfect-Jet MCV-M8 machining centre. The cutting tool is clamped to the machine table and the experimental workpiece is fixed in the tool holder of the machine. The fast rotation of the spindle assured the main cutting movement, while the CNC controlled circular motion of the tool around the rotating workpiece resulted the secondary

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feed motion. The clamped tool with the helical cutting edge for rotational feed and the workpiece can be seen in Figure 1.

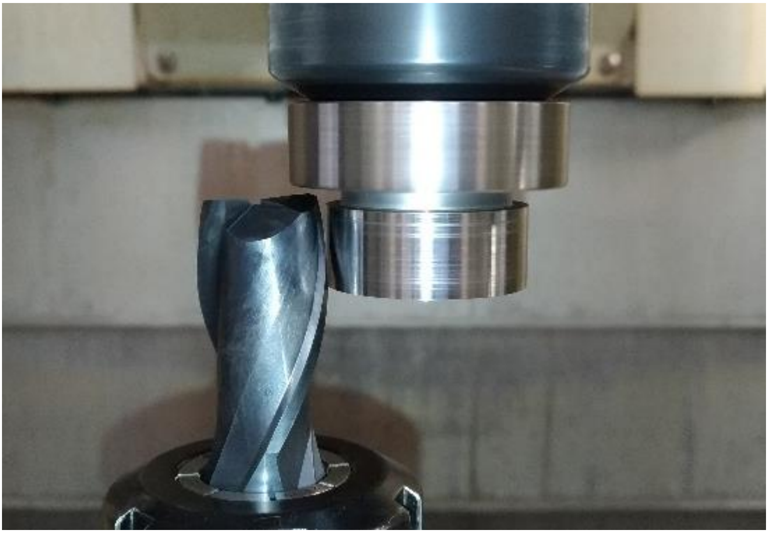

Figure 1 – Geometrical and kinematical relations of rotational turning

A heat-treated C45 steel grade is machined during the experiments, which had a 12 mm length Ø40 mm diameter surface. The circular feed was realized by two rotational turning tools: Fraisa P5300682 (λ_s = 30°, notation: A) and Sandvik Coromant R215.38-20050-AC38L (λ_s = 50°, notation: B). The result of the rotational turning are compared with a standard longitudinal turning tool (CNMG 120412-PM insert in DCLNL 2525 M 12 holder, notation: C). The experiments are carried out with 200 m/min and 250 m/min cutting speed (v_c), 0.1 mm depth of cut and five values of feed (f) for each cutting tool (f = 0.1 mm, 0.2 mm, 0.4 mm, 0.6 mm, 0.8 mm). The machined surfaces are measured by a Mitutoyo SurfTest SJ-301 2D roughness measuring device on three generatrix of the cylindrical part. The measured length and cut-off length are adjusted according to DIN EN ISO 4288.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The roughness measurement results of the Arithmetical mean deviation of the assessed profile (R_a) and the Average peak to valley height of the profile (R_z) are shown in Table 1 for Tool A, Table 2 for Tool B and Table 3 for Tool C.

Table 1 – Roughness measurement results for Tool A

v_c [m/min]	**f [mm]**	**$R_{a,1}$ [µm]**	**$R_{a,2}$ [µm]**	**$R_{a,3}$ [µm]**	**$R_{z,1}$ [µm]**	**$R_{z,2}$ [µm]**	**$R_{z,3}$ [µm]**
200	0.1	0.47	0.45	0.48	3.22	2.83	3.05
	0.2	0.47	0.48	0.49	3.82	3.79	3.73
	0.4	0.54	0.55	0.57	3.58	3.54	3.45
	0.6	0.73	0.69	0.74	5.18	5.19	5.67
	0.8	1.2	1.39	1.28	7.42	7.16	7.24
250	0.1	0.45	0.44	0.44	3.04	2.95	3.07
	0.2	0.45	0.45	0.44	3.81	3.80	3.78
	0.4	0.6	0.63	0.61	4.6	4.49	4.27
	0.6	0.76	0.74	0.78	5.95	5.19	5.39
	0.8	1.1	1.18	1.08	6.89	7.32	6.87

Table 2 – Roughness measurement results for Tool B

v_c [m/min]	**f [mm]**	**$R_{a,1}$ [µm]**	**$R_{a,2}$ [µm]**	**$R_{a,3}$ [µm]**	**$R_{z,1}$ [µm]**	**$R_{z,2}$ [µm]**	**$R_{z,3}$ [µm]**
200	0.1	0.53	0.46	0.47	3.46	2.91	2.74
	0.2	0.39	0.39	0.36	3.21	3.40	2.66
	0.4	0.93	0.90	0.87	4.79	4.66	4.50
	0.6	2.01	1.91	1.91	9.86	9.36	8.94
	0.8	4.75	3.99	3.93	19.59	17.73	18.8
250	0.1	0.34	0.34	0.33	2.62	2.77	2.86
	0.2	0.34	0.34	0.32	2.24	2.12	2.08
	0.4	0.73	0.68	0.71	4.16	4.21	3.95
	0.6	2.28	2.33	2.38	10.54	10.84	10.71
	0.8	3.65	3.64	3.66	16.58	16.52	16.51

Table 3 – Roughness measurement results for Tool C

v_c [m/min]	**f [mm]**	**$R_{a,1}$ [µm]**	**$R_{a,2}$ [µm]**	**$R_{a,3}$ [µm]**	**$R_{z,1}$ [µm]**	**$R_{z,2}$ [µm]**	**$R_{z,3}$ [µm]**
200	0.1	0.49	0.49	0.48	2.01	1.91	1.76
	0.2	0.96	0.99	0.94	4.44	5.00	4.46
	0.4	3.36	3.27	3.27	13.52	13.44	13.35
	0.6	6.68	6.49	6.57	25.74	25.54	25.67
	0.8	10.66	10.78	10.53	40.37	40.15	40.52
250	0.1	0.48	0.48	0.47	1.93	1.93	1.85
	0.2	0.99	0.92	1.02	4.77	4.42	4.84
	0.4	2.97	3.09	3.08	12.61	12.38	12.61
	0.6	6.69	6.65	6.86	26.08	26.16	26.55
	0.8	10.15	9.96	9.85	38.83	38.59	38.83

The mean values for the different setups are calculated and shown in Table 4. The machining times (t_m) are also determined for the comparison of productivity by the application of the results of previous studies [6]. This parameter means the required time to produce the machined surface, therefore it can be used for the comparison of productivity of turning procedures with different kinematics.

The results of the roughness evaluations are shown in Figure 2. The values increase only in a small extent on surfaces machined by Tool A, which has a 30° inclination angle. On lower feeds ($f \leq 0.4$ mm) the growth is almost negligible, while increasing the feed from 0.4 mm to 0.8 mm results in an almost two-fold increase in the roughness parameters on various speeds. Machining by Tool B resulted in a nearly constant surface roughness on 0.1 mm and 0.2 mm feeds. The increase of the roughness values can be observed from 0.2 mm feed, from where the alteration can be described as an exponential growth. If the feed is higher than this limit, a 0.2 mm increase in the feed results in a nearly two-fold increase in R_a and R_z for both v_c.

Table 4 – Mean values of the roughness parameters and the machining times

Tool	**f [mm]**	**v_c = 200 m/min**			**v_c = 250 m/min**		
		$R_{a,a}$ [µm]	**$R_{z,a}$ [µm]**	**t_m [s]**	**$R_{a,a}$ [µm]**	**$R_{z,a}$ [µm]**	**t_m [s]**
A	0.1	0.466	3.033	4.53	0.443	3.02	3.86
	0.2	0.48	3.78	2.76	0.446	3.796	2.20
	0.4	0.553	3.523	1.36	0.613	4.453	1.09
	0.6	0.72	5.346	0.90	0.76	5.51	0.72
	0.8	1.29	7.273	0.67	1.12	7.026	0.53
B	0.1	0.486	3.036	5.65	0.336	2.75	4.50
	0.2	0.38	3.09	2.95	0.333	2.146	2.35
	0.4	0.9	4.65	1.39	0.706	4.106	1.11
	0.6	1.943	9.386	0.82	2.33	10.696	0.73
	0.8	4.223	18.706	0.61	3.65	16.536	0.49
C	0.1	0.486	1.893	4.01	0.476	1.903	3.19
	0.2	0.963	4.633	1.92	0.976	4.676	1.53
	0.4	3.3	13.436	0.92	3.046	12.533	0.73
	0.6	6.58	25.65	0.59	6.733	26.263	0.47
	0.8	10.656	40.346	0.43	9.986	38.75	0.34

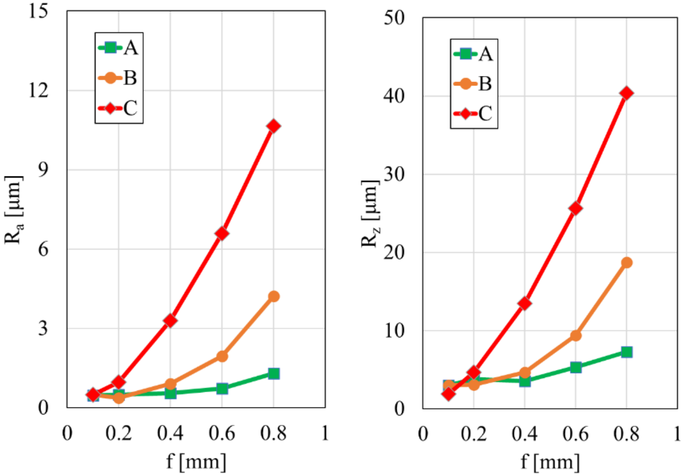

Figure 2 – Mean values of the roughness parameters (v_c = 200 m/min)

The results of the measurements made on surfaces machined by a traditional turning tool are not presented any nearly constant roughness values on the studied setups. Here the exponential growth starts from 0.1 feed.

The comparison of different tools leads into the following conclusions. Machining with 0.1 mm feed resulted in nearly the same R_a values for the three cutting tools, however the measured R_z parameters showed differences. The average peak to valley height of the profile was lowest in traditional turning from which a 1.5-fold higher results measured after machining with rotational turning. I got this outcome because on this feed not the geometry of the cutting tool is significant in the surface texture generation, but the secondary deformations, material structure etc. However, the order of the cutting tools changes on 0.2 mm feed. The lowest roughness was achieved by Tool B, while Tool C becomes the worst. From this feed, the cutting edge geometry starts to play more important role on the surface texture. On 0.4 mm, 0.6 mm and 0.8 mm feeds the lowest roughness values measured on surfaces machined by Tool A, while the highest roughness is produced by Tool C. It can be also seen that the results from machining by Tool C can be achieved with nearly 2 times higher feeds with tool B and 3 times higher feeds with tool A. That means that rotational turning is more efficient: more surfaces can be machined during the same period. This is further analysed in Figure 2, where the roughness values are shown in function of the machining time. It can be seen, that the production of especially smooth surfaces ($R_a < 0.4$ µm,

R_z < 3.5 μm) needs more time (thus 0.1 mm feed). However, to get a finished surface (R_a < 1.0 μm, R_z <6.0 μm), rotational turning requires half of time machining time than traditional turning. The difference between the ratio of feeds and machining time is caused by the higher needed run-in and run-out time in circular feed.

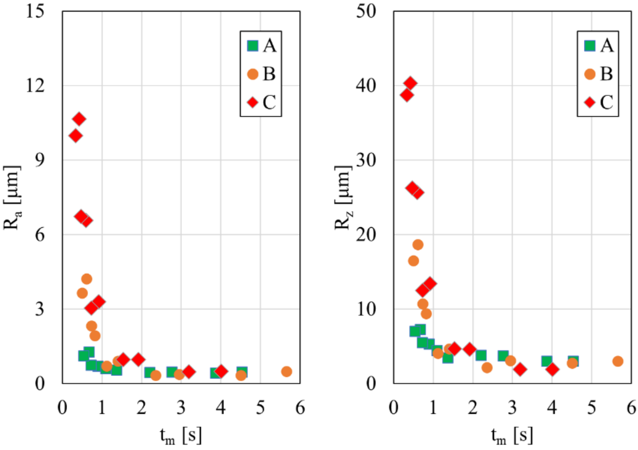

Figure 3 – Roughness measurement results in function of the machining time

SUMMARY

The Arithmetical mean deviation of the assessed profile and the Average peak to valley height of the profile surface roughness parameters and the machining times are compared on different feeds in machining by traditional and rotational turning. Cutting experiments were made with five feeds, two cutting speeds and three cutting tools. From the mean values of the measured R_a and R_z values it is concluded that the application of rotational turning results in a significantly lower surface roughness than the values of traditionally machined surfaces. Comparing the needed machining time showed that 0.5-fold lower machining time needed in rotational turning to achieve a nearly ground surface.

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ВПЛИВ КРУГОВОЇ ПОДАЧІ НА ШОРСТКІСТЬ ПОВЕРХНІ І ТРИВАЛІСТЬ ОБРОБКИ

Анотація. *Метою даної роботи є аналіз значень шорсткості і часу обробки при різанні циліндричних поверхонь з різною кінематикою і геометрією крайок (обертальне і поздовжнє точіння). В даному дослідженні експериментальні роботи проводилися на обробному центрі Perfect-Jet MCV-M8. Різальний інструмент затискається на столі верстата, а експериментальна заготовка фіксується в тримачі інструменту. Швидке обертання шпинделя забезпечувало основний рух різання, в той час як керований ЧПУ круговий рух інструменту навколо заготовки, що обертається під час обробки, здійснював рух вторинної подачі. Порівняння різних інструментів дозволяє зробити наступні висновки. Обробка з подачею 0,1 мм дала майже однакові значення R_a для трьох різальних інструментів, проте виміряні параметри R_z показали відмінності. Середня висота профілю від піку до западини була найменшою при традиційному точінні, а після обробки з обертальним точінням результати були в 1,5 рази вище. Цей результат було отримано тому, що на цій подачі важлива не геометрія різального інструменту в створенні текстури поверхні, а вторинні деформації, структура матеріалу і т.п. Однак порядок різальних інструментів змінюється при подачі 0,2 мм. Найменша шорсткість була досягнута інструментом B, а інструмент C -— найгіршим. З цієї подачі геометрія різальної крайки починає грати більш важливу роль в текстурі поверхні. На 0,4 мм, 0,6 мм і 0,8 мм припадають найнижчі значення шорсткості, виміряні на поверхнях, оброблених за допомогою інструменту A, в той час як найвища шорсткість досягається за допомогою інструменту C. Також можна бачити, що результати обробки за допомогою інструменту C можуть бути досягнуті з подачі майже в 2 рази вище для інструменту B і в 3 рази вище для інструменту A. Це означає, що обертальне точіння більш ефективне: за той же період можна обробити більше поверхонь. Видно, також, що для виготовлення особливо гладких поверхонь (R_a <0,4 мкм, R_z <3,5 мкм) потрібно більше часу (таким чином, подача 0,1 мм). Однак для отримання чистової поверхні (R_a <1,0 мкм, R_z <6,0 мкм) обертальне точіння вимагає вдвічі менше часу обробки, ніж традиційне. Різниця між співвідношенням подач і часом обробки викликана більш високим необхідним часом припрацювання і вибігання при круговій подачі.*

Ключові слова: *час обробки; обертальне точіння; шорсткість поверхні.*