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ARITHMETIC MEAN HEIGHT AND MAXIMUM HEIGHT OF THE ROUGHNESS PROFILE IN HONING WITH DIFFERENT FEEDS

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Abstract. *The achievable surface quality is an important factor even in roughing procedures; however, it is most relevant in finishing. Two commonly measured and analysed characteristics of the machined surface roughness profile are the Arithmetic Mean Height and the Maximum Height of the Roughness Profile. In this paper these parameters were studied in bore honing. Cutting experiments were carried out, where the feed rate and the applied honing tool are varied. After the evaluation of the measured 2D surface profiles, the following conclusions were drawn: the effect of the feed rate is not linear; the lowest values of the analysed roughness parameters were achieved by the application of 50 mm/rev. feed rate and a honing tool with 80 grain size and ceramic binder; the difference between the studied roughness parameters was 6.5-8.0-fold.*

Keywords: *arithmetic mean height of roughness profile; cutting; experiments; honing; maximum height of roughness profile.*

1. INTRODUCTION

The study of the achievable surface quality is an important task in machining, most importantly in finish procedures. A part of the evaluation of the machined surface quality is the analysis of the geometric errors on the surface, which can be done by the investigation of 2D roughness parameters. It is necessary to specify the optimal process parameters to optimize surface roughness [1,2]. Though much research is ongoing in this field [3,4], it is not an easy task to give the optimal setup parameters. It is also a difficult task in abrasive machining. A part of this is the study of the cutting tool, where the change in the area and the maximum stress with a change in the grain concentration are established [5]. Yang et al. found, that increasing the grain size results in increased surface roughness by more than four times [6]. The radial and axial speed had little effect on the roughness in their work. Szabó showed that by changing the grain material it is possible to effectively influence the amount of material removed from the workpiece in a unit of time [7]. In their work, Sabri et al showed that by changing the material (and especially the grain size) of the honing tool, the final surface roughness and topography of the machined workpieces can be favourably influenced [8]. It was found that a higher elastic modulus of the bond can increase the strength of abrasive material, which provides an increase in grinding performance and a reduction in the specific consumption of grains [9]. Goelden et al. proved with their simulation and experimental work that the prescribed roughness can be achieved with fewer strokes by increasing the pressure [10]. The abrasive cutting process is also affected by the selected binder of the tool [11,12].

In this paper, the Arithmetic Mean Height and the Maximum Height of the Roughness Profile are studied in bore honing by changing the feed rate and the material of the tool. The values of these parameters were measured and analysed.

2. EXPERIMENTAL CONDITIONS AND METHODS

The aim of the experiments was to study the effect of several parameters (pressure, feed, grain size) on the surface roughness in bore honing. The values of the analysed parameters were chosen according to the rules of 23 full factorial design of experiments.

The machining was done with the different setups on a WMW 270/700 honing machine, which was provided by Belcord Kft. in Eger, Hungary (their help is greatly appreciated). The honing experiments were carried out on sleeves with EN-GJL-250 lamellar cast iron alloy material, 192 mm bore length and 88 mm inner diameter. Three kinds of honing tools were used, which had Al_2O_3. The specifications of the different honing tools can be seen in Table 1.

Among the cutting parameters, the cutting speed (v_c) was fixed to 200 m/min and the applied pressure on the honing stone (p) was adjusted to 10 bar. The feed per revolutions (v_f) was set to 25 mm/rev, 50 mm/rev and 75 mm/rev. The resulted setups and the set parameters can be seen in Table 2.

Table 1 – Honing tool characteristics

Mark	Grain size	Binder	Structure
I	80	ceramic	medium dense
II		synthetic resin	dense
III	240		

Table 2 – Experimental setups

Setup number	1	2	3	4	5	6	7	8	9
Bore length [mm]	192	192	192	192	192	192	192	192	192
Bore diameter [mm]	88	88	88	88	88	88	88	88	88
Cutting speed	200	200	200	200	200	200	200	200	200

[m/min]									
Pressure [bar]	10	10	10	10	10	10	10	10	10
Feed rate [mm/rev.]	25	25	25	50	50	50	75	75	75
Honing tool no.	1	2	3	1	2	3	1	2	3

Measurements were carried out on the workpieces after the cutting experiments with a Mitutoyo SJ-301 Surftest roughness measurement device. The roughness profiles were registered on three generatrix of each bore. The measured profiles were evaluated with the AltiMap Premium 6.2.7487 surface analysis software. The analysed parameters of the 2D (linear) profile were (ISO 21920:2021):

- *Ra* – Arithmetic Mean Height of the roughness profile [µm]
- *Rz* – Maximum Height of the roughness profile [µm]

3. EXPERIMENTAL RESULTS

The experiments were carried out and the surface profiles are measured for each setup. Figure 1 shows the roughness profile of the machined surfaces after the machining with 25 m/min feed were carried out with the three tools. Figure 2 presents the three different results in case of 50 m/min feed. Lastly, the roughness profiles corresponding to the 75 m/min feed can be seen in Figure 3.

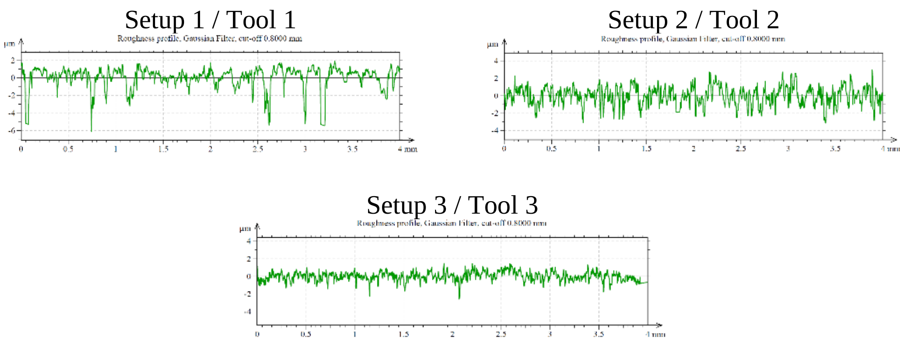
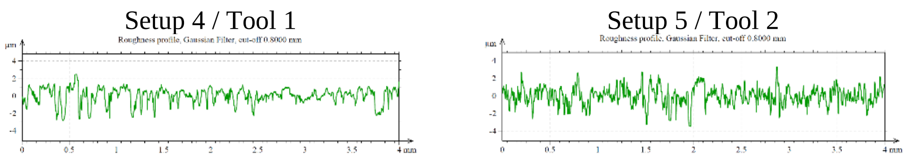


Figure 1 – Roughness profiles measured after machining with 25 m/min feed rate



Setup 6 / Tool 3

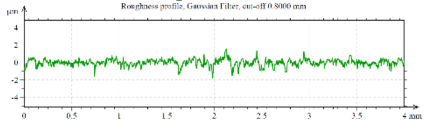
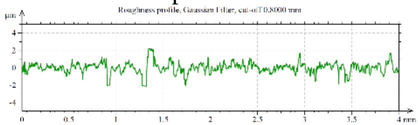
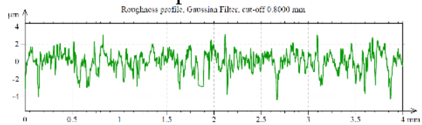


Figure 2 – Roughness profiles measured after machining with 50 m/min feed rate

Setup 7 / Tool 1



Setup 8 / Tool 2



Setup 9 / Tool 3

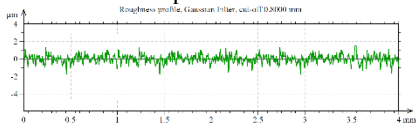


Figure 3 – Roughness profiles measured after machining with 75 m/min feed rate

Table 2 – Measurement results

Setup		1	2	3	4	5	6	7	8	9
R_a [μm]	1	0.86	0.80	0.40	0.67	0.79	0.31	0.98	1.02	0.50
	2	0.68	0.82	0.42	0.68	0.77	0.31	0.80	0.99	0.31
	3	0.68	0.74	0.25	0.69	0.80	0.28	0.75	0.89	0.36
	Mean	0.74	0.79	0.36	0.68	0.79	0.30	0.84	0.97	0.39
R_z [μm]	1	6.17	5.06	3.16	4.67	5.02	2.16	7.44	7.33	3.70
	2	6.01	5.31	2.97	4.09	5.41	2.13	5.97	6.23	1.99
	3	5.17	5.08	1.91	3.89	4.79	2.10	7.23	6.70	2.48
	Mean	5.78	5.15	2.68	4.22	5.08	2.13	6.88	6.75	2.72

The resulted profiles were evaluated, and the analysed roughness values were determined for each setup. Then the mean values of the three measurements of R_a and R_z were calculated for each setup These values are shown in Table 2.

4. DISCUSSION

The evaluation of the results follows the assessment of the measurements. Figure 4 presents the Arithmetic Mean Height of the roughness profile in function of the feed rate and the used honing tool. As the feed rate increased from 25 mm/rev. to 50 mm/rev. and lastly 75 mm/rev, an interesting phenomenon could be noticed.

Among these three setup parameters, the middle value resulted the lowest R_a in all three types of honing tools. The increase of v_f from 50 mm/rev. to 75 mm/rev. results in a 20% increase in R_a, while the decrease of the studied setup parameter resulted in a 10% increase in this roughness parameter. This suggest that the effect of the feed rate is not linear contrary to other finish machining procedures as bore turning. Therefore the choice of feed rate for honing procedure is a complex task and further considerations must be taken into account in the process planning. The effect of the proper choice of honing tool material is more significant. If a coarser grain structure is applied, the roughness will be higher in both type of applied binders. However, if the finer grains are applied, a nearly two-fold decrease in the R_a value can be expected. This relation is expected since the size of the grains corresponds to the size of the micro-scratches generated on the machined surface.

Figure 5 shows the alteration of Maximum Height of the roughness profile in function of the feed rate and the selected honing tools. The trend of the change is similar to the previously described alteration. However, the application of synthetic resin instead of a ceramic binder led to higher R_a values in feeds of 25 mm/rev. and 75 mm/rev., yet the R_z values became lower. This suggest that the selected binder affects the chip removal, this leading to a different shaped surface profile as it can be seen in Figure 1-3. In the studied parameter range, the difference between R_a and R_z was 6.5-8.0-fold. This differs from the usually applied ratio of 5 in machining with defined cutting edged tools.

a) b)

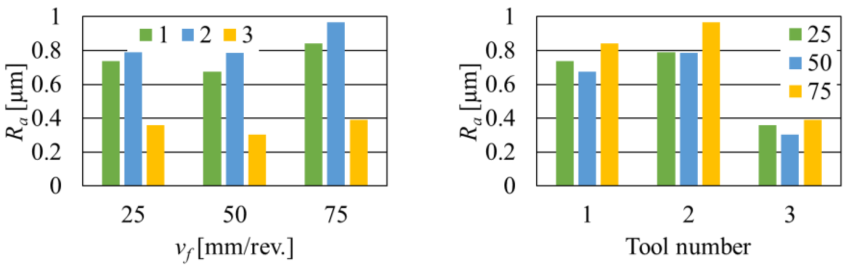


Figure 4 – Arithmetic Mean Height of the roughness profile in function of feed rate (a) and applied tool (b)

a) b)

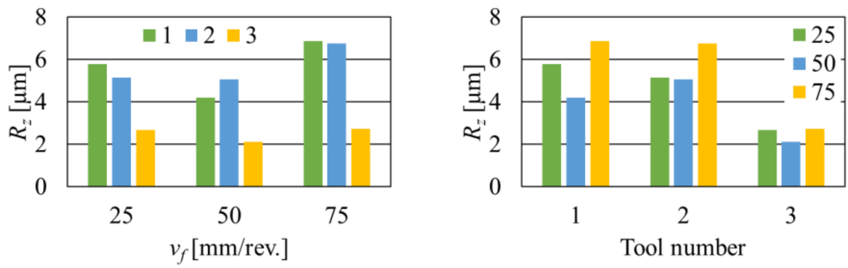


Figure 5 – Maximum Height of the roughness profile
in function of feed rate (a) and applied tool (b)

5. CONCLUSIONS

The study of the expectable machined surface roughness is needed particularly in finish procedures. Honing is a widely used chip-removal procedure in the production of good quality bores due to its advantageous characteristics. In this paper, the Arithmetic Mean Height and the Maximum Height of the roughness profile are analysed. Cutting experiments were carried out by the application of different kinds of honing tools and feed rate. The machined surfaces were measured and evaluated.

The following conclusions can be highlighted after the evaluation of the experimental results:

- The effect of the feed rate on the studied roughness parameters is not linear.
- Minimal values of the analysed roughness parameters were got using 50 mm/rev. feed rate and a honing tool with 80 grain size and ceramic binder.
- The difference between R_a and R_z was 6.5-8.0-fold.

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Іштван Станкович, Мішкольц, Угорщина

СЕРЕДНЬО АРИФМЕТИЧНЕ І МАКСИМАЛЬНЕ ЗНАЧЕННЯ ВИСОТИ ПРОФІЛЮ ШОРСТКОСТІ ПРИ ХОНІНГУВАННІ З РІЗНИМИ ПОДАЧАМИ

Анотація. *Досяжна якість поверхні є важливим фактором навіть при чорнових процедурах, однак найбільш актуальна вона при обробці. Дві загальноприйняті та проаналізовані характеристики профілю шорсткості оброблюваної поверхні – це середня арифметична висота та максимальна висота профілю шорсткості. Механічна обробка проводилася за допомогою різних установок на хонінгувальному верстаті. Експерименти з хонінгування проводилися на гільзах з пластинчастого чавуного сплаву EN-GJL-250, довжиною отвору 192 мм і внутрішнім діаметром 88 мм. Використовувалися три види хонінгувальних інструментів, на основі* Al_2O_3*. Серед параметрів різання, швидкість різання (*v_c*) була зафіксована на рівні 200 м/хв, а прикладений тиск на хонінгувальний брусок (p) був відрегульований до 10 бар. Подача на оберт (*v_f*) була встановлена на 25 мм/об, 50 мм/об і 75 мм/об. Вимірювання проводилися на заготовках після проведених експериментів з різання приладом для вимірювання шорсткості Mitutoyo SJ-301 Surftest. Профілі шорсткості були зареєстровані на трьох твірниках кожного отвору. Виміряні профілі були оцінені за допомогою програмного забезпечення для аналізу поверхні AltiMap Premium 6.2.7487. Проаналізовані параметри 2D (лінійного) профілю були (ISO 21920:2021):* R_a *– середня арифметична висота профілю шорсткості [мкм],* R_z *– максимальна висота профілю шорсткості [мкм]. У даній роботі ці параметри були вивчені при хонінгуванні отворів. Були проведені експерименти з різанням, де варіюється швидкість подачі і застосовуваний хонінгувальний інструмент. Після оцінки виміряних 2D профілів поверхні були зроблені наступні висновки: вплив швидкості подачі не є лінійним; найнижчі значення аналізованих параметрів шорсткості були досягнуті застосуванням швидкості подачі 50 мм/об та хонінгувального інструменту з розміром зерна 80 та керамічного в'яжучого; Різниця між досліджуваними параметрами шорсткості становила 6,5–8,0 разів.*

Ключові слова: *середнє арифметичне значення висоти профілю шорсткості; різання; експерименти; хонінгування; максимальна висота профілю шорсткості.*