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I. Sztankovics, G. Nagypál, Miskolc, Hungary

SURFACE QUALITY OF HONED BORES AS A FUNCTION OF PRESSURE FORCE

Abstract. *The effect of the pressure force and tool material structure on the surface roughness and straightness of honed bores is studied in this paper. We measured the vertical straightness, the arithmetic average and the maximum height of the roughness profile in our experiments, which contained 9 setups. We compared the registered profiles from the measuring devices in addition to the values of the three quality parameters.*
Keywords: *honing experiments; aluminium oxide abrasive; surface roughness; straightness.*

1. INTRODUCTION

During construction design, among the different accuracy and roughness instructions a specific surface structure can be prescribed on the surfaces of mechanical parts based on the functional requirements. The prescribed instructions on the particular workpiece surfaces often require the application of a specific machining procedure. One example for this is the expectation for the inner cylinder bores of a combustion engine block, namely, to ensure the proper bearing ratio among the low surface roughness. The most often used finishing procedures in the machining of bores are grinding and fine turning, as shown in Kundrák et al. [1,2], however honing has been shown to be the optimal solution in the finish machining of these cylinder bores [3].
The main process parameters of multi-stroke bore finishing (honing) are tool revolutions, pressure force, stroke length and stroke number. We analyse the alteration effect of the pressure in this paper. Based on their analytical model and experiments, Gao et al. proved that an increase in the pressure between the grinding stones and the bore surface leads to a nearly linear increase in the removed material per unit of time, which increases the material removal rate [4]. Goelden et al., applying a simulation and experimental work, proved that the prescribed roughness can be reached with a lower stroke number by increaseing the pressure force [5]. On the machined surface roughness Szabó showed [6] that a minimal roughness value can be identified as a function of the pressure from which point the roughness will become higher by either increasing or decreasing the pressure force. We can see from the study of Zhou et al. [7], that the geometrical inhomogeneity of the abrasive stone grain structure leads to an increase in the machined surface roughness. With the proper choice of the tool material and the decrease of the pressure force,

friction loss can be lowered, as shown in the work of Karpuschewski et al. [8]. Burkhard et al. proved in their experimental work that tool life and productivity can be increased by the proper choice of the grain positions and structure [9].
It can be seen from the above that the alteration of the pressure force and the material/structure of the abrasive tool effectively affects the machined surface roughness. Therefore, we present in this paper from our study the effect of machining with different tool materials and pressure force on the surface roughness and straightness.

2. EXPERIMENTAL CONDITIONS

For the honing experiments, we chose sleeves with an 88 mm bore diameter and 192 mm length. The workpiece material was EN-GJL-250 lamellar cast iron alloy. During the experiments, three types of aluminium oxide abrasive cutting tools were used with different structure, grain sizes and binding material on the WMW 270/700 honing machine. The data of the tools are summarized in Table 1.

Table 1 – Applied abrasive cutting tools

Abbreviation	A	B	C
Grain material	Al_2O_3		
Grain size code	80		240
Binding material	ceramic	synthetic resin	
Structure	medium	dense	

During the cutting experiments, the axial speed and the revolutions of the tools were held constant at 50 m/min and 725 1/min m/min, respectively, based on the information from automotive companies. The aim of our study is to analyse the pressure force alteration effect, therefore 3 pressure values (7 bar, 10 bar and 13 bar) were adjusted for each grinding tool. The parameters for the resulting 9 setups are summarized in Table 2.

Table 2 – Experimental setups

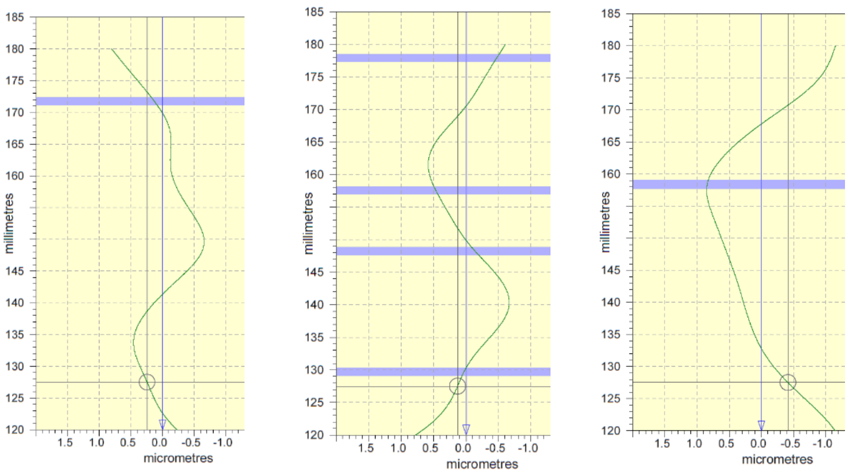
No.	Tool	Pressure	Axial speed	Tool revolutions
1	A	7 bar	50 m/min	725 1/min
2	B			
3	C			
4	A	10 bar		
5	B			
6	C			
7	A	13 bar		
8	B			
9	C			

3. EXPERIMENTAL RESULTS

Measurements were carried out on the workpieces after the cutting experiments with a Mitutoyo SJ-301 Surftest roughness measurement device and Talyrond 365 shape and position error measurement machine. We measured the vertical straightness (STRt), the arithmetic average (Ra) and the maximum height (Rz) of the roughness profile on three generatrix of each bore. For the corresponding parameters the mean values were calculated (Table 3).

Table 3 – Mean values of the surface quality measurements

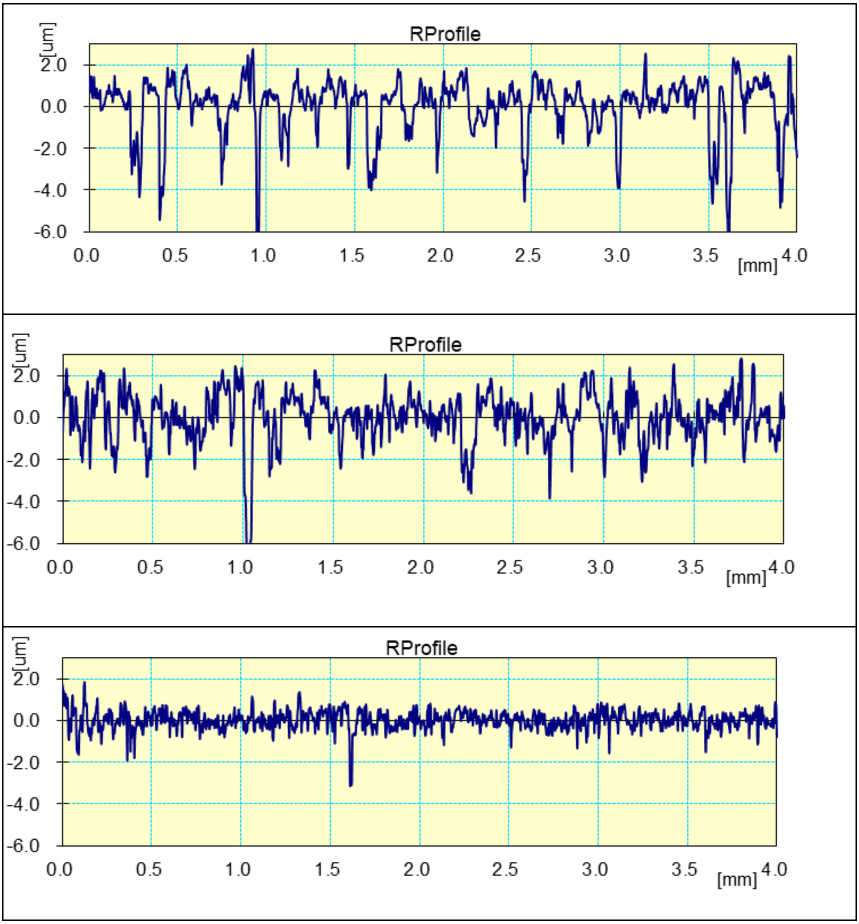
	1	2	3	4	5	6	7	8	9
Ra [μm]	3.06	2.48	0.82	0.93	0.71	0.18	0.87	0.95	0.32
Rz [μm]	16.40	17.50	7.57	5.83	4.78	1.32	7.91	7.31	3.39
STRt [μm]	1.72	1.80	1.34	1.45	3.12	3.62	1.68	1.87	1.95



7 8 9

Figure 1 – Straightness measurement results for the three tools at 13 bar pressure

Figure 1 shows the results of the surfaces registered by the shape error measuring machine filtered according to the standard for Setup 7-9. We can see the axial position in the bore on the Y axis and the radial deflection on the X axis. The blue zones show the regions filtered by the program. Analysed R profiles of the same setups during the roughness measurements are shown in Figure 2. The X axis represent the axial displacement of the gauge and the filtered data of the registered surface is shown in the Y axis.



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8

9

Figure 2 – Roughness measurement result for the three tools at 13 bar pressure

4. DISCUSSION

The experimental results presented in Table 3 are shown in diagrams in Figure 3-5. Based on these we drew the following conclusions.

From the viewpoint of the surface straightness, the better results were achieved with the rougher tool with higher porosity. This can be seen in Figure 1, where waviness of lower amplitude and periodicity can be observed on the surface machined by tool A (7), than on the surface machined by tool C (9). The worst case from the perspective of STRt was that with 10 bar pressure and smaller abrasive grain size. For the setups machined with 7 and 13 bar pressure, the measured straightness was almost half of the value from the worst setup (6).

Analysing the roughness measurement results, we can see from Figure 2 that a smoother surface can be achieved with the tool with lower grain size and denser structure. From the setups shown in Figure 2, Setup 7 shows a deeper profile than Setup 9. Based on the values and Figures 4–5 we conclude that the most favourable roughness is achieved by the tool with smaller grain size at all pressures. Values of Rz and Ra can be lowered 3-4-fold by the proper choice of the cutting tool.

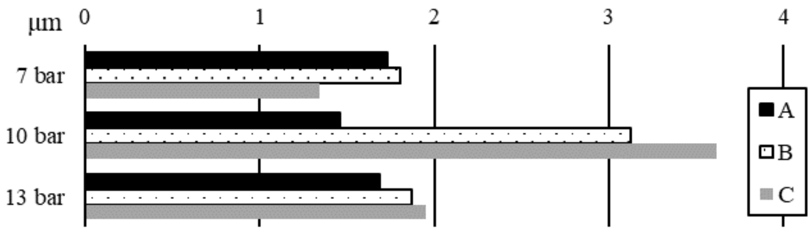

Figure 3 – Results of the straightness measurements (STRt)

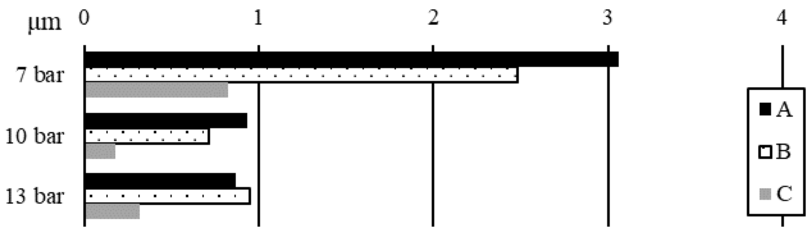

Figure 4 – Results of the arithmetic mean of the roughness profiles (Ra)

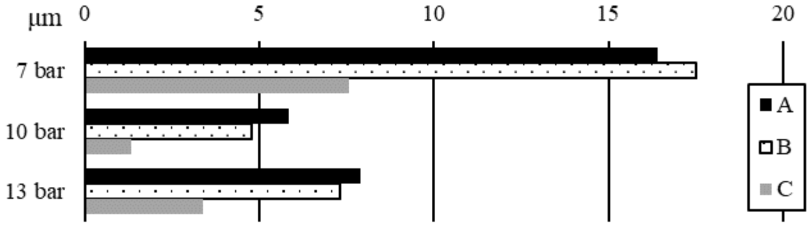

Figure 5 – Results of the maximum height of the roughness profiles (Rz)

The pressure effect results demonstrate that the local minimum in the roughness values described in the literature also appeared in our experiments, because the lowest surface roughness was measured at 10 bar pressure. From the results of Setup 4–6, a 20% increase can be seen in the roughness values with 13 bar pressure. The roughness values achieved at 7 bar pressure are 3-4-fold worse than the measurements at 10 bar pressure.

SUMMARY

The analysis of the machined surface quality and awareness of the effect of each process parameter are important in finishing procedures. We studied the surface straightness and roughness of honed inner cylindrical bores at different pressure forces and with tool structure of different abrasiveness. We showed in our analysis of 9 setups that for surface straightness, bigger grain size and lower density is favourable; furthermore, the lowest roughness error is measured at 10 bar pressure from the chosen values. Both studied parameters have a significant effect on the surface roughness. Surface roughness can be effectively decreased by the increase of the pressure between the tool and workpiece and by the decrease of the grain size when the other process parameters remain unchanged.

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Іштван Станкович, Гергель Надьпал,
Мішкольц, Угорщина

ЯКІСТЬ ПОВЕРХНІ ОТВОРІВ ПІСЛЯ ХОНІНГУВАННЯ ЯК ФУНКЦІЯ СИЛИ ПРИТИСКУ

Анотація. *У статті вивчається вплив сили притиску і структури матеріалу інструменту на шорсткість поверхні і прямолінійність хонінгованих гільз автомобільних блоків циліндрів. Для експериментів по хонінгуванню були вибрані гільзи з діаметром отвору 88 мм і довжиною 192 мм, Матеріал заготовки - пластинчастий сплав чавуну. У ході експериментів на хонінгувальному верстаті WMW 270/700 використовувалися три типи абразивних ріжучих інструментів з оксиду алюмінію з різною структурою, розмірами зерна і зв'язуючим матеріалом. Прямолінійність виміряли по вертикалі (STRt), середнє арифметичне (Ra) і максимальну висоту (Rz) профілю шорсткості вимірювали на трьох твірних кожного отвору. Для відповідних параметрів були розраховані середні значення. Були проведені дослідження прямолінійності поверхні і шорсткість хонінгованих внутрішніх циліндричних отворів при різних силах притиску і при різній структурі абразивного інструменту. Аналізуючи результати вимірювання шорсткості стало видно, що більш гладка поверхня може бути досягнута за допомогою інструменту з меншим розміром зерна і більш щільною структурою. На підставі отриманих значень можна зробити висновок, що найбільш сприятлива шорсткість досягається інструментом з меншим розміром зерна при всіх тисках. Мета даного дослідження - проаналізувати ефект зміни сили притиску, тому для кожного хонінгувального інструменту були скориговані 3 значення тиску (7 бар, 10 бар і 13 бар). Параметри для отриманих 9 установок були зведені в таблиці. З аналізу 9 установок видно, що для прямолінійності поверхні краще більший розмір зерна і менша щільність. Крім того, самий низький рівень помилки шорсткості вимірюється при тиску 10 бар з вибраних значень. Обидва вивчених параметри істотно впливають на шорсткість поверхні. Шорсткість поверхні може бути ефективно зменшена шляхом збільшення тиску між інструментом і оброблюваною деталлю і шляхом зменшення розміру зерна, коли інші параметри процесу залишаються незмінними.*

Ключові слова: *хонінгування; абразиви оксиду алюмінію; шорсткість поверхні; прямолінійність.*