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COMPARISON OF FINISH MACHINING PROCEDURES ON THE BASIS OF MATERIAL REMOVAL PERFORMANCE

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ПОРІВНЯННЯ ПРОЦЕСІВ ЧИСТОВОЇ ОБРОБКИ, ЩО БАЗУЄТЬСЯ НА ЗНЯТТІ МАТЕРІАЛУ

Пропонується порівняти економічні аспекти процесів – абразивну механічну обробку й механічну обробку різанням – на основі інтенсивності зняття матеріалу. Порівняння різних процесів обробки було виконано відповідно до критеріїв оцінки якісних вимог обробки заготовок. У даній роботі економічна ефективність процесів механічної обробки – шліфування, свердління й комбіновані процеси – проаналізована на основі часу механічної обробки, номінальної поверхневої потужності і інтенсивності знімання матеріалу.

Ключові слова: альтернативна обробка, інтенсивність зняття матеріалу (MRR), номінальна поверхнева потужність (SR)

Предлагается сравнить экономические аспекты процессов – абразивную механическую обработку и механическая обработка резанием – на основе интенсивности съема материала. Сравнение различных процессов обработки было выполнено согласно критериям оценки качественных требований обработки заготовок. В данной работе экономическая эффективность процессов механической обработки – шлифование, сверление и комбинированные процессы – проанализирована на основе времени механической обработки, номинальной поверхностной мощности и интенсивности съема материала.

Ключевые слова: альтернативная обработка, интенсивность съема материала (MRR), номинальная поверхностная мощность (SR)

It is suitable to compare the economy of procedures so much different in material removal – like abrasive machining and machining with edges – on the basis of material removal rates. The comparison of different hard cutting procedures was carried out in compliance with the evaluation criteria that were the quality requirements in producing the workpieces. In this paper the economic efficiency of the machining procedures – grinding, turning, and combined procedures – is analysed on the basis of the machining times, the surface rate and the material removal rate.

Keywords: alternative machining, material removal rate (MRR), surface rate (SR)

INTRODUCTION

Nowadays actuality of the machining method selection is underlined by the comparison of grinding and hard turning when manufacturing hard surfaces.

Many practical applications require components to be hardened in order to improve their wear behavior.

The enhancement of the durability of parts is associated with the formation of ever harder surfaces as well as a higher number of hard surfaces. But it is also noticeable that surfaces are increasingly more often hardened to shorten the technological chain (to simplify the technological process).

In the manufacturing chain, the hardening process is usually followed by a finishing operation that generates the component's final geometry [1], [2].

The finish machining of hard surfaces can be done first of all by grinding, hard turning as well as by the combination of the two procedures.

It is production engineering task to compare and optimally select these machining versions on technical, economic bases. The technological conditions under which grinding and hard turning can be alternatives to perform a given process had been examined earlier [3, 4], and they were examined by us too [5, 6, 7, 8, 9]. The machining procedures by which all the accuracy and quality prescriptions of the examined component can be met are considered alternatives to each other.

In this paper examinations are outlined that focus on with what economic efficiency the chosen alternative procedures can perform the quality requirements prescribed for the part. The effectiveness of the machining processes was analysed on the bases of the surface rate, the operation times, and the material removal rate.

2. EXPERIMENTS

The experiments were made for bore-holes of IT5-IT6 accuracy when surface roughness Rz=5 μm was to be provided.

1.1. The examined procedures

The examined procedures by which it was possible to provide the prescribed surface quality and accuracy were as follows:

a) internal traverse grinding (symbol: **G**)
b) hard turning: roughing and smoothing with standard insert (symbol: HT_S)
c) hard turning: roughing with wiper insert, smoothing with standard insert (symbol: HT_W+S)
d) combined procedure: roughing with standard insert, smoothing with corundum wheel (symbol: C_S+Cor)
e) combined procedure: roughing with wiper insert, smoothing with corundum wheel (symbol: C_W+Cor)
f) combined procedure: roughing with standard insert, smoothing with CBN wheel (symbol: C_S+CBN)
g) combined procedure: roughing with wiper insert, smoothing with CBN wheel (symbol: C_S+Cor)

1.2. The technological characteristics of the examined workpieces and machining

Two bore-holes with different diameters, and identical lengths were machined. The data of the workpiece were as follows:

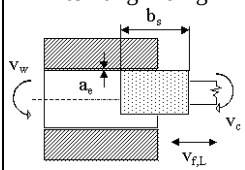
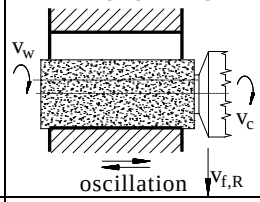
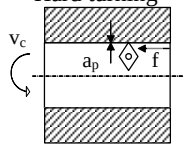
material	16MnCr5;	length of bore:	27.35;
hardness:	61÷63 HRC;	ℓ/d relationship:	0.41÷0.57;
diameters:	d=48 (sign A), d=66 (sign B);	allowance:	0.3 mm (in diameter);
accuracy:	IT 5-6;	sequence size:	n=200.

From 0.15 mm allowance 0.1 mm-s were removed by roughing, 0.05 mm-s by smoothing. The characteristic technological data are summarized in Table 1.

Table 1 – Technological data of cutting bore-holes

Process	Machine tool / Tool	Condition data	
		Roughing	Smoothing
Grinding	SI-4/A 40x40x16-9A80-K7V22	v_c=25…29 m/s v_w=14…19 m/min $v_{f,L}$=2.2 m/min	v_c=25…29 m/s v_w=14…19 m/min $v_{f,L}$=2 m/min
Hard turning	PITTLER PVSL-2 CNGA 120408S-LO CBN CNGA 120408 7020	v_c=180 m/min f=0.08…0.15 mm/rev. a_p=0.10 mm	v_c=180 m/min f=0.12…0.24 mm/rev. a_p=0.05 mm
Combined process	EMAG VSC 400 DS CNGA 120408S-LO CBN 40x40x16-9A80-K7V22	v_c=180 m/min f=0.24 mm/rev. a_p=0.1 mm $v_{f,R}$=0.0033 m/min	v_c=25…29 m/s v_w=14…19 m/min $v_{f,R}$=0.0016 m/min

Table 2 – Formulas of material Removal Rate and Surface Rate

Processes	Internal grinding	Plunge grinding	Hard turning
			
Theoretical value of the Material removal rate Q_w [mm^3/s]	$Q_w = a_e \cdot f \cdot v_w$	$Q_{w,elm,N} = L_3 \cdot v_{f,R} \cdot d_1 \cdot \pi$	$Q_w = a_p \cdot f \cdot v_c$
Prractical value of the Material removal rate Q_w [mm^3/s]	$Q_{wp} = \frac{d_1 \cdot \pi \cdot L_3 \cdot Z}{t_{op} \cdot 60}$		
Theoretical value of the Surface rate A_w [mm^2/s]	$A_w = f \cdot v_w$	$A_w = L_3 \cdot v_w$	$A_w = f \cdot v_c$
Practical value of the Surface rate A_w [mm^2/s]	$A_{wp} = \frac{d_1 \cdot \pi \cdot L_3}{t_{op} \cdot 60}$		

where:

a_e – depth of cut (mm); (grinding);
a_p – depth of cut (mm); (turning);
v_w – surface speed of the workpiece (mm/s);
$v_{f,R}$ – plunge speed (mm/s);
v_c – cutting speed (mm/s);
f – feed rate (mm/workpiece rev.);
d_1 – diameter of the workpiece (mm);
L_3 – length of the workpiece (mm);
t_{op} – operating time (min).

2.3. Measurement numbers of comparison

In calculating of different theoretical values, the value of the surface and/or the volume to be removed regarding to a time unit has been used for a long time – mainly using the different, possible cutting data of a process.

These measurement numbers are as follows (Table 2):

material removal rate (MRR)

- Q_w (mm^3/s)

surface rate (SR)

- A_w (mm^2/s).

These measurement numbers had been examined by us before [7, 8] and also outlined that a corrected ("practical") interpretation was introduced for the process examination to make the comparison more accurate.

These practical parameters express how many mm^2–s of surface can be made ready and also how many mm^3–s of material can be removed in 1 s by the given machining procedure under the conditions of the prescribed accuracy and surface quality.

We can calculate the practical value of the material removal rate Q_{wp} by dividing the material volume of the allowance by the time required for its removal.

$$Q_{wp} = \frac{d_1 \cdot \pi \cdot L_4 \cdot 0.3}{t_x \cdot 60} \ (mm^3/s), \tag{1}$$

We calculate the practical surface rate (A_{wp}) by dividing the size measure of the surface to be machined by the time required for its production:

$$A_{wp} = \frac{d_1 \cdot \pi \cdot L_4}{t_x \cdot 60} \quad (mm^2/s). \tag{2}$$

The earlier analysis of practical parameters proved [7, 8] that with them we can express the efficiency of material removal and they are in accordance with the real machining times and expenditure.

That is why our examinations focused on defining the practical values, and $Q_{wp,op.}$ (mm^3/s), $A_{wp,op.}$ (mm^2/s) values comparison referring to the operation times are given.

3. RESULTS

The two bore-holes were machined by seven possible versions. The operation times, the practical values of surface rate and material removal rate were defined.

Grinding takes longest operation time. In hard turning the operation time of a 48 mm bore reduces to its quarter, which reduces even lower by application of wiper inserts (Figure 1). By increasing the diameter, the difference between the operation times reduces; however, in machining the 68 mm bore (Figure 2) the operation time of hard tuning is still only the third of that of grinding.

The difference in operation times can be that big because the surface rate and the material removal performance is significantly higher in hard turning.

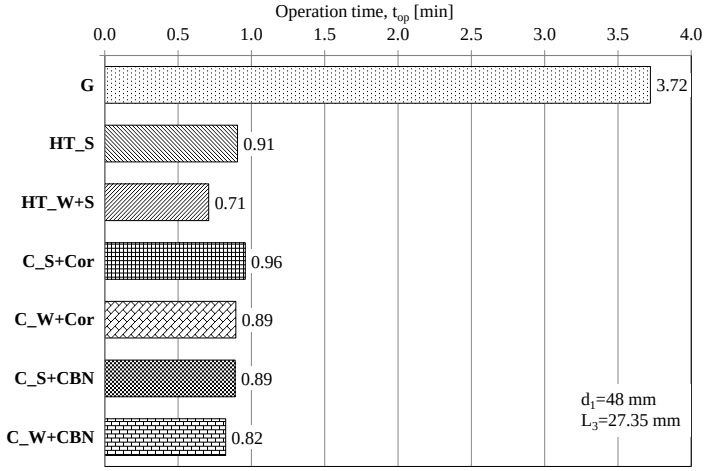


Figure 1 – Operation times in different procedures in piece signed **A**

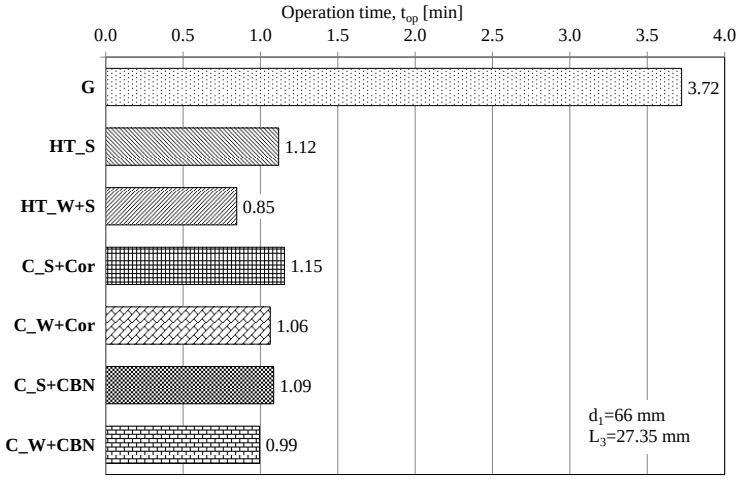


Figure 2 – Operation times in different procedures in piece signed **B**

Having a smaller diameter, the surface rate is four times higher, which can be over five times higher if applying a wiper insert (Figure 3). Increasing the diameter, the difference in the surface rate decreases 3.3 times, which can be increased to 4.6 times if applying a wiper insert. The proportions are similar in the material removal performance as well (Figures 5, 6).

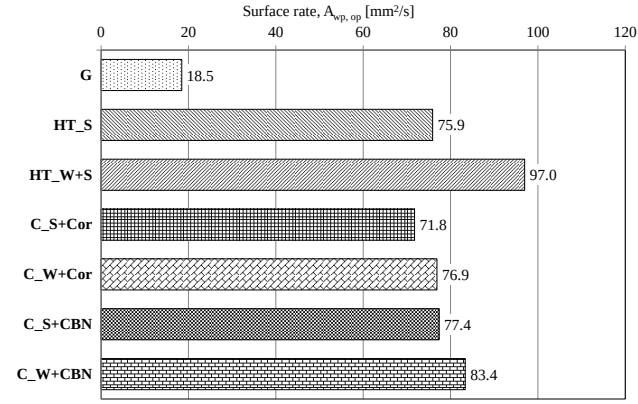


Figure 3 – Surface rate on the basis of operation time ($A_{wp,\ op}$) in piece signed **A**

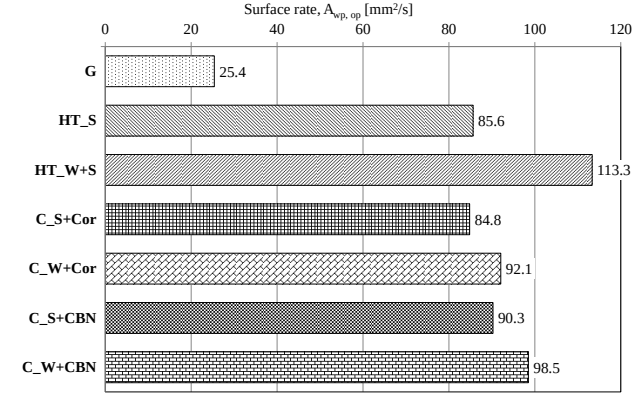


Figure 4 – Surface rate on the basis of operation time ($A_{wp,\ op}$) in piece signed **B**

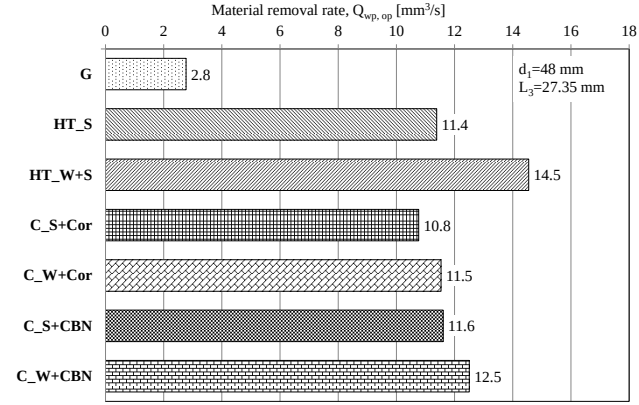


Figure 5 – Material removal rate on the basis of operation time ($Q_{wp,\ op}$) in piece signed **A**

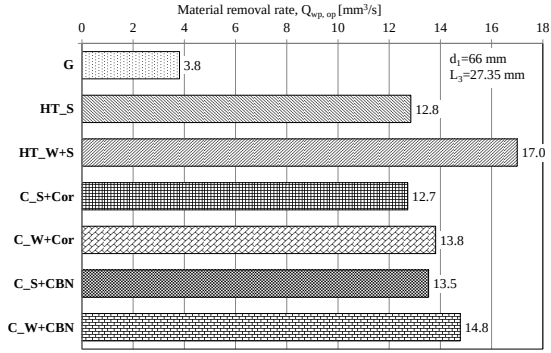


Figure 6 – Material removal rate on the basis of operation time ($Q_{wp, op}$) in piece signed **B**

This unambiguously proves the advantage of hard turning.

First of all because its productivity is multiple compared to grinding, however, its process cost is much smaller, and it is an environmentally friendly technology. Apart from those it ensures the accuracy, roughness and surface quality parameters on the same level as grinding.

However, in finish machining not always the proceeding carried out by tools with geometrically defined cutting edges is the most beneficial.

If the functional requirements for the part need ground topography it is suitable to choose a finish procedure with which the economic efficiency can be ensured as well.

The condition for that is that the bigger possible portion of the allowance should be removed by turning and only the allowance minimally needed for creating the topography should be ground. If it is done in a traditional way, because of the higher number of machine tools and clampings, the economic efficiency will not be remarkably better than if applying only grinding.

This, time the hybrid machining come to the front, which typically does not require another machine-tool, but together with hard turning it is done on the same machine-tool.

From Figure 1-6 it can be seen that with the applied procedures in creating ground topography, economic efficiency can be reached similar to that of hard turning carried out by a standard insert.

CONCLUSION

Such a comparison of hard turning and grinding for internal cylindrical surfaces shows an important advantage of the economic efficiency of hard turning as compared to grinding.

The practical values of the material removal rate (MRR) and surface rate (SR) reveal the existing differences, therefore they are suitable for comparing alternative machining procedures.

In most cases there are the technical and technological conditions of the substitution of grinding with hard turning in most cases at present.

There are cases when the functional conditions require ground topography. The most important motive is to avoid the periodic topography being disadvantageous on sealing surfaces, at bearing areas and synchronous cones as well.

In a case like that, the application of the so called combined (hybrid) machining is suggested.

It means the application of a hybrid machine on which the workpieces are machined with one clamping on one machine altering automatically either the turning tools or the grinding tools as needed.

Our investigations proved that by combined procedures, economic efficiency can be reached similar to that of hard turning.

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