15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

SELECTION OF PROCEDURES IN FINISHING OF HARDENED STEEL TAKING INTO ACCOUNT ECONOMIC ASPECTS

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ABSTRACT
Investigation of hard machining is one of the major trends of cutting procedures. According to technical and technological development, hardened steels can be machined today with several processes referring to the accuracy and quality requirements of the precision parts. The paper compares the applicable procedures taking into account some economic aspects.
Keywords: alternative machining, material removal rate (MRR), surface rate (SR)

1. INTRODUCTION

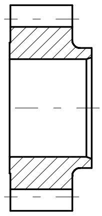
We find more and more hardened surfaces on components machined by precision procedures. Considering the ordered accuracy and surface quality requirements for these surfaces we can choose among more machining procedures to produce them. The rate of abrasive machining processes among these procedures is reducing, while machining with defined edge geometry becomes more widespread. In most cases the same roughness and accuracy can be ensured with more procedures. At the same time the running requirements of built-in parts limit the application possibilities.
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 can be done first of all by grinding, hard turning as well as by the combination of the two procedures.
It is a 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 before [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.

2. EXPERIMENTAL CONDITIONS

The experiments were made for gear bore-holes of IT5 accuracy when surface roughness Rz=5 μm was to be provided. Table 1 summarizes the sign and description of the procedures we investigated and the draft of the workpiece.
The data of the workpiece were as follows: material: 16MnCr5; hardness: 61÷63 HRC; diameter: d=66; accuracy: IT 5; length of bore: 27.35; ℓ/d relationship: 0.41; allowance: 0.3 mm; sequence size:

n=200. From 0.15 mm allowance 0.1 mm were removed by roughing, 0.05 mm by smoothing. The characteristic technological conditions are summarized in Table 2.

Table 1. Draft of the workpiece and the summary of the investigated procedures

Workpiece	Process			
	Sign	Description	Procedure	
			Roughing	Smoothing
	**A**	internal traverse grinding	corundum wheel	corundum wheel
	B	hard turning	standard insert	standard insert
	C		wiper insert	standard insert
	D	combined procedure	standard insert	corundum wheel
	E		wiper insert	

3. APPLIED METHODS OF THE EXPERIMENT

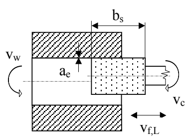
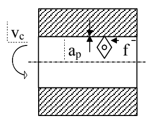
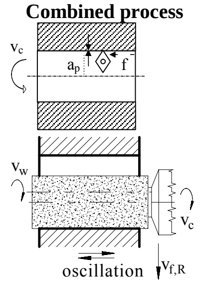
In calculating of different theoretical values, the value of the surface and/or the volume to be removed regarding to a time unit has been used for a long time – mainly using the different, possible cutting data of a process. These measurement numbers are as follows:

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. 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.

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

Table 2. Technological conditions of cutting bore-holes

Process		**Grinding** 	**Hard Cutting** 	**Combined process** 
Machine tool / Tool		**SI-4/A** 40x20x16-9A80-K7V22	**PITTLER PVSL-2** CNGA 120408S-LO CBN CNGA 120408 7020	**EMAG VSC 400 DS** CNGA 120408S-LO CBN 40x40x16-9A80-K7V22
Condition data	Smoothing	v_c=25…29 m/s v_w=14…19 m/min $v_{f,L}$=2.2 m/min	v_c=180 m/min f=0.24 mm/rev. a_p=0.10 mm	v_c=180 m/min f=0.24 mm/rev. a_p=0.1 mm v_w=14…19 m/min $v_{f,R}$=0.0033 m/min
	Roughing	v_c=25…29 m/s v_w=14…19 m/min $v_{f,L}$=2 m/min	v_c=180 m/min f=0.12 mm/rev. a_p=0.05 mm	v_c=25…29 m/s v_w=14…19 m/min $v_{f,R}$=0.0016 m/min

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:

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

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.
Our examinations focused on defining the practical values referring $Q_{wp,op.}$ (mm^3/s), $A_{wp,op.}$ (mm^2/s) values of operation time.

4. RESULTS

The operation times, the practical values of surface rate and material removal rate were defined for five possible versions of machining. Grinding takes longest operation time. In hard turning the operation time of a gear-wheel reduces to approximately 30 percent. It can be reduced even lower by application of wiper inserts (Figure 1). The surface rate is three times higher, which can be over four times higher if applying a wiper insert (Figure 2). The proportions are similar in the material removal performance as well (Figures 3).

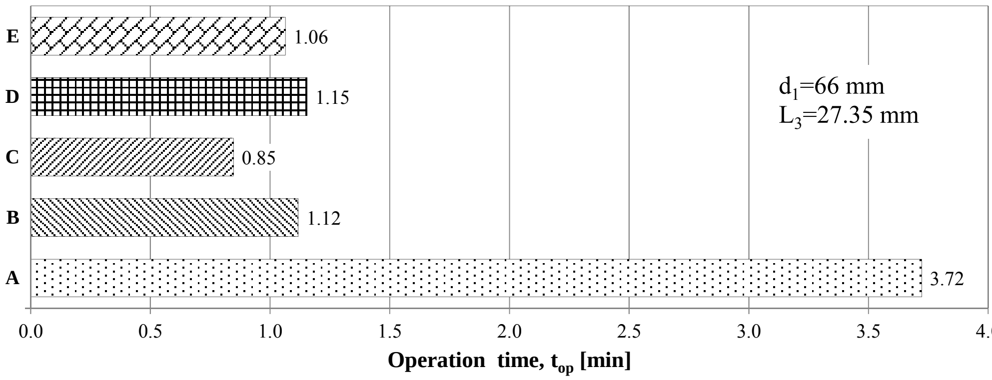


Figure 1. Operation times in different procedures

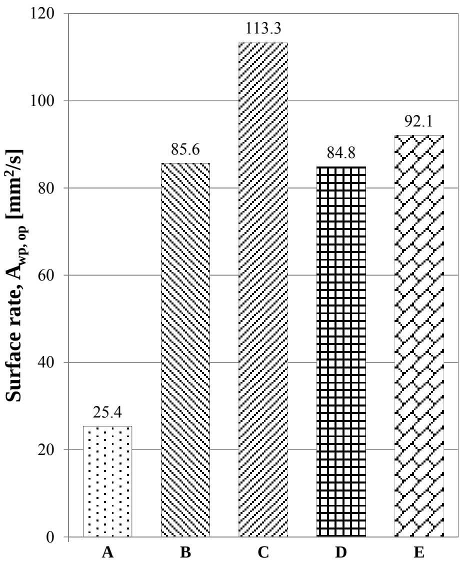


Figure 2. Surface rate on the basis of operation time ($A_{wp,\ op}$)

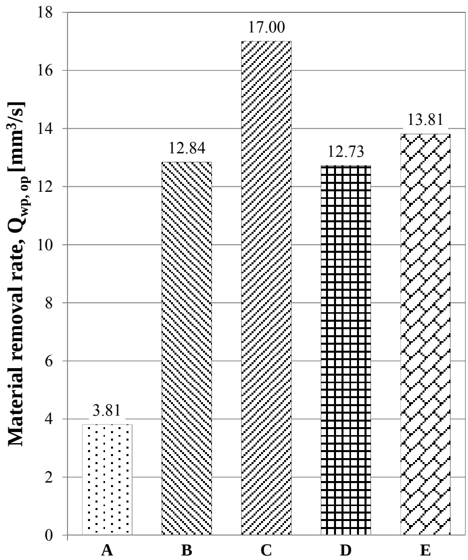


Figure 3. Material removal rate on the basis of operation time ($Q_{wp,\ op}$)

This unambiguously proves the advantage of hard turning. Apart from those it ensures the accuracy, roughness and surface quality parameters on the same level as grinding.
If the functional requirements for the part need ground topography it is suitable to combine the two procedures properly. The condition for that is that the biggest 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 Figures 1-3 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.

5. CONCLUSION

In machining hardened steels there are the technical and technological conditions of the substitution of grinding with hard turning in most cases at present.
Such a comparison of hard turning and grinding for gear-wheel machining 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. There are cases when the functional conditions of the components built in the product require ground topography.
In a case like that, the application of the so called combined (hybrid) machining is suggested. On a hybrid machine 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.

6. ACKNOWLEDGEMENT

The work was presented by the support of the Hungarian Scientific Research Fund (Number of Agreement: OTKA K 78482 and OTKA 84177), which the authors greatly appreciate.
The described work was carried out as part of the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project.

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