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DEVELOPMENT IN MACHINING TECHNOLOGY

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This study aims to provide the recent advances in machining for modern manufacturing engineering, especially CNC machining, modern tools and machining of difficult-to-cut materials, optimization of machining processes, application of measurement techniques in manufacturing, modeling and computer simulation of cutting processes and physical phenomena.

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PREFACE

Machining is one of the most popular technique to change shape and dimensions of the objects. Machining operations can be applied to work metallic and non-metallic materials such as ceramics, composites, polymers, wood.

Cutting tools have been used since ancient times to remove excess material from forgings and castings. Nowadays, metal cutting became one of the primary manufacturing processes for finishing operations. In the last few years we have observed a rapid development in automation of manufacturing processes, especially in automatic control systems. Progress in cutting stimulates a significant increase in the metal removal rate and achieving high accuracy in terms of dimensions and shape of machine parts. New materials, which play the key role here, are used to produce cutting tools.

To meet today's high demands concerning accuracy and efficiency of the manufacturing process of machine parts, it is necessary to use computer methods for designing of technological processes.

This study aims to provide the recent advances in machining for modern manufacturing engineering, especially CNC machining, modern tools and machining of difficult-to-cut materials, optimization of machining processes, application of measurement techniques in manufacturing, modeling and computer simulation of cutting processes and physical phenomena.

Wojciech Zębala

PART 1

Machining of Difficult-To-Cut Materials

Chapter 1.2

RATES OF USED-UP COOLANT AND LUBRICANT IN HARD MACHINING

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Abstract: *The application of coolant and lubricants generally increase the efficiency of material removal, the quality of machining and the accuracy of the produced components. However, the used auxiliary products pollute the environment; hence we have to endeavour to reduce the quantity of them as much as possible. In this paper the comparing analysis of the hard machining procedures is performed on the basis of the used up coolant and lubricants (CL).*

Keywords: *coolant and lubricant, hard machining, environmental load*

1. Introduction

Most of the cutting procedures use up significant quantity of CL. It helps to increase the cooling and the lubrication effects and the flush and wash effects too. Increasing of performance of the procedures has been resulting in the increase of the use of CL for a long time. Therefore, significant quantities are used up. These quantities referring to the EU are shown in Table 1. On the one hand, it covers a large market; on the other hand it means a dreadful effect referring to environment pollution and health hazard [1].

CL-s are applied in the cutting procedures (e.g. turning, milling, drilling) and in the abrasive procedures (e.g. grinding) too. The increasing environmental awareness indicates a new paradigm in the industry. In this paradigm eco-efficiency is a new key-word. The focus is not only on the energy consumption or waste handling but on the alternative costs of non-sustainable industrial practices.

It is known that the coolant and lubricant increases the efficiency of machining in several cases but there is a new determinant of efficiency too. It is the costs and risks of the use of them. In Fig. 1 the distribution of costs in connection with the coolants and lubricants used in the automotive industry machining can be seen. It has to be noted that the costs of coolants and lubricants are significantly higher than the costs of tooling.

Table 1. An overview of the market of CL in the EU [1] [2]

Group of materials	Sales in Germany (t/a)	Total sales in EU (t/a)
All lubricants*	1 146 844	5,2 million
CL out of them	78 877	360 000
Water-immiscible CL	48 170	220 000
Water-immiscible CL (concentrate)	30 707	140 000
Emulsions and solutions made from water-miscible CL	ca 770 000	ca 3,5 million
All used up CL	ca 820 000	ca 3,7 million

*It has to be noted that these statistical data do not include the mineral oil free CL-s. The market share of these mineral oil free CL-s is 20% in proportion of the total produced water-miscible CL-s.

CL's are applied in the cutting procedures (e.g. turning, milling, drilling) and in the abrasive procedures (e.g. grinding) too. The increasing environmental awareness indicates a new paradigm in the industry. In this paradigm eco-efficiency is an important variable. The focus is not only on the energy consumption or waste management but on the alternative costs of non-sustainable industrial practices. It is known that the coolant and lubricant increases the efficiency of machining in several cases but there is new determinant of efficiency too. It is the costs and risks of the use of them. In Fig 1 the distribution of costs being in connection with the coolants and lubricants used in the automotive industry machining can be seen. It has to be noted that costs of coolants and lubricants are significantly higher than costs of tooling.

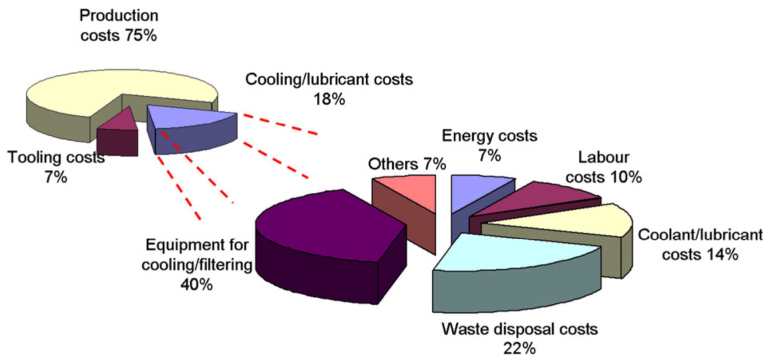


Fig. 1. Distribution of cooling/lubricant costs in machining operations in the automotive industry
(data from a Danobat-Ideko internal report, updated in March 2010) [3]

Sectors with high added value like vehicle industry, energy sector, high-speed trains etc. are the consumers of products made by high performance procedures. These consumers demand components made of hard materials, close tolerance and their machining must result in high surface quality. The demands are increased referring partly to precision machining, partly to the life cycle of components. These components are ready machined by hard machining procedures [4,5,6,7,8 and 9] and the produced and built in quantity is typically large. In this work we analyse to what extent the quantity of CL-s can be reduced with the appropriate choice of the machining procedures.

2. Experiments

Comparative investigations were performed for machining hardened surfaces of given accuracy and surface roughness to get information about the used up coolant and lubricants.

Method of investigation

Grinding has been the most frequently used hard machining procedure for long decades. Therefore the basis of comparison was the machining performed by grinding. We had to choose the technological conditions of the other procedures so that the accuracy and the quality requirements reached by the grinding procedure could be fulfilled in every case of machining. Performing the machining with the data determined this way we considered the operation times which are in proportion with the quantity of the used up coolant and lubricants. Therefore we can give two pieces of information: the quantity of the used up CL-s in the rate of operation time and the rate of CL-s compared to the grinding.

Characteristics of the machined workpiece

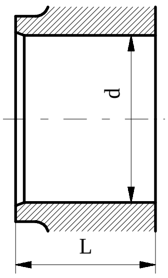
The experiments were made for bore-holes of cog wheels in gear boxes with IT5 accuracy when surface roughness was Rz=5 μm to be provided. The data of the workpiece were as follows: material: 16MnCr5; hardness: 61÷63 HRC; diameter: d=66; accuracy: IT 5; length of bore: 27.35; l/d relationship: 0.41; allowance: 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 investigated procedures

We analysed five procedures. While not only roughness and accuracy parameters are essential referring to the functionality of the part but the

surface topography too, we also considered that in our experiments. Ground profile was machined by three kind of different procedures. These were the following: Conventional internal grinding (traverse grinding) (G); combined procedure (CP I.): roughing with standard insert and smoothing with high-speed infeed grinding; combined procedure (CP II.): roughing with Wiper insert and smoothing with high-speed infeed grinding. Turned profile was machined by two kinds of procedures: standard (HB I.) and Wiper (HB II.).
Table 2 summarizes the procedures investigated and the geometrical conditions of the workpiece surface.

Table 2. Geometrical data and the investigated procedures

<table>
<tr><td>Workpiece</td><td colspan="4">Process</td></tr>
<tr><td rowspan="7">

d = 30..70 mm
L = 40..80 mm</td><td rowspan="2">Sign</td><td rowspan="2">Description</td><td colspan="2">Procedure</td></tr>
<tr><td>Roughing</td><td>Smoothing</td></tr>
<tr><td>G.</td><td>internal traverse grinding</td><td>corundum wheel</td><td>corundum wheel</td></tr>
<tr><td>HB I.</td><td rowspan="2">hard boring</td><td>standard insert</td><td>standard insert</td></tr>
<tr><td>HB II.</td><td>wiper insert</td><td>standard insert</td></tr>
<tr><td>CPI.</td><td rowspan="2">combined procedure</td><td>standard insert</td><td>corundum wheel</td></tr>
<tr><td>CP II.</td><td>wiper insert</td><td>corundum wheel</td></tr>
</table>

3. Results and their interpretation

Operation times of the machining procedures

In Table 3 the values of operation times are given. It can be seen that this time is the longest in case of grinding since the material removal rate of this procedure is the smallest (2.3-5.3 mm^3/s depending on the geometrical conditions of the bore-hole). Hard turning is characterized by significantly higher material removal rate; therefore its operation time is can be 7-times smaller.

The combined procedure is characterized by its ground profile, however, only a minimum allowance is removed by grinding to form the topography. The rest of the material is removed by hard turning on the same machine tool in the same clamping. Another difference to conventional grinding is the applied procedure which is infeed grinding, which requires less time. That is why this method allows to form ground profile during times close to the times of hard cutting.

Table 3. Operation times of the machining procedures

Bore-hole diameter d, [mm]	Bore-hole length L, [mm]	Procedure				
		G	HB I.	HB II.	CP I.	CP II.
50	40	4.61	1.18	0.89	1.00	0.91
	60	6.23	1.58	1.15	1.13	0.98
	80	7.85	1.99	1.41	1.25	1.06
30	60	6.23	1.09	0.83	0.98	0.89
50		6.23	1.58	1.15	1.13	0.98
70		6.23	2.08	1.48	1.28	1.08

CL consumption in hard machining

The quantity of the applied coolant and lubricant is determined by the characteristics of the grinding and the hard turning, since the other procedures are the combination of them.

During the machining time of grinding a large amount of CL is used continuously in order to perform appropriate material removal. Therefore this procedure pollutes the environment significantly and damages the health of the employees; furthermore the operation costs are higher too.

Hard machining is a dry procedure; accordingly it is more advantageous from ecological view. Therewith the residual side products originated from the cutting process are less environment pollutant and it is easy to recycle them.

Comparing the other procedures to grinding, the CL consumption is given by the operation times and in the combined procedure by the rate of times of turning and grinding. The reason for that is that the roughing is done by dry procedure (turning) and the smoothing (grinding) is done by the application of CL in case of combined procedure.

Extent of environmental load in the examined hard manufacturing procedures

First we analysed the quantity of the used up CL-s by the different versions of procedures, while the machining was performed with the cutting data providing the same accuracy of the workpiece and the same surface roughness. Grinding requires CL in the whole operation (100%). This rate is 0% by dry cutting. In the other machining versions it was demonstrated how high is the rate of the grinding in the operation time. In Fig. 2 it is shown how much is the rate of dry machining in a given procedure for a concrete bore-hole (d=30mm, L=60mm). In Fig. 3 the operation times are shown and the rate of used up CL within that.

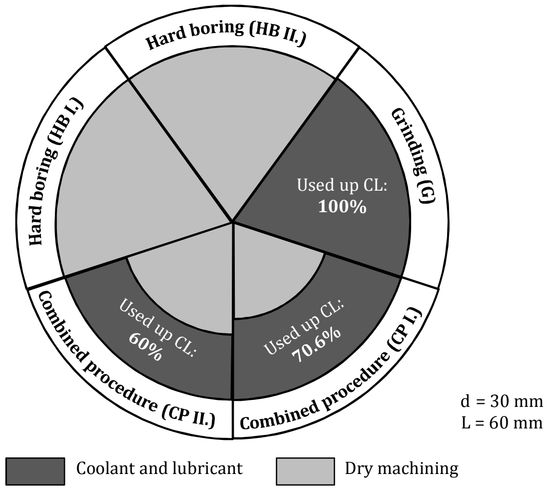


Fig. 2. The rate of CL consumption in the operation time

In Table 4 the same values are given referring to the investigated geometrical data. It is shown that the ground surface can be machined so that only 40-60% of CL (CP I.) and 50-70% of CL (CP II.) needs to be used up during the operation.

Table 4. CL Used up for boring within the operation time

Bore-hole diameter d, [mm]	Bore-hole length L, [mm]	Procedure				
		G	HB I.	HB II.	CP I.	CP II.
50	40	100%	0%	0%	57.12	68.07
	60				47.44	59.08
	80				40.56	52.19
30	60				60.06	70.64
50					47.44	59.08
70					39.19	50.77

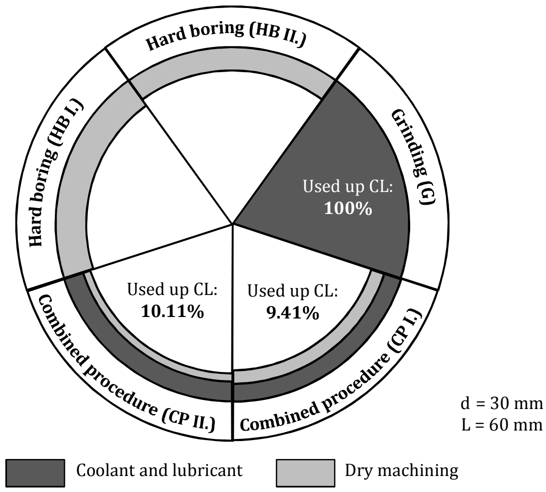


Fig. 3. The rate of CL consumption related to grinding
(Denominations according to Table 3)

Concerning the aspect of environmental load, the replacement of grinding with combined procedures is essential by itself too (Table 5).

Table 5. CL used up for in relation to grinding

Bore-hole diameter d, [mm]	Bore-hole length L, [mm]	Procedure				
		G	HB I.	HB II.	CP I.	CP II.
50	40	100%	0%	0%	12.46	13.44
	60				8.57	9.34
	80				6.44	7.05
30	60				9.41	10.11
50					8.57	9.34
70					8.03	8.79

The saving of the whole CL amount and the reducing of environmental load being in proportion with it can be given in relation to the quantity used up by grinding. The values demonstrate outstanding reduce, because only 13% of the originally used up quantity is necessary even in the most disadvantageous case. We intend to emphasize again that the application of hard turning performed without any CL is recommended if ground topography is not necessary.

Hard turning which requires the shortest operation time can be done dry. If grinding is performed to remove the total allowance in order to get a ground profile, we not only get the longest operation time but the largest CL consumption too. Therefore, to provide ground topography, the combined procedure is suggested, because its operation time is hardly any longer than that of grinding, however, its CL consumption is only one-tenth of grinding.

4. Conclusion

In case of the bore-holes with the investigated geometrical sizes, the replacement of the conventional grinding with the other investigated hard machining procedures must be suggested. Hard turning is a relatively new procedure, which provides rare possibilities in precision manufacturing: while the environmental load is reduced significantly, at the same time the material removal rate can remarkably be increased. Accordingly it is expedient to apply that whenever the functional requirements of the workpieces facilitate it.

If ground topography is necessary, the application of the combined procedure is recommended. In this case too, the operation time nearly equal to hard turning can be held, while the rate of the used up CL is reduced to its one-tenth comparing to grinding, besides the investigated geometrical data.

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References

[1] PUSAVEC F., KRAJNIK P. KOPAC, J. (2010) *Transitioning to sustainable production – Part I: application on machining technologies*. Journal of Cleaner Production. 18:174–184.

[2] BAUMANN W. GRAFEN M., POLLKLASNER D. (1999) *Assessment of the environmental release of chemicals used in metal-cutting and forming fluids*. Emission scenario document – metal extraction industry, refining and processing industry. IC8. Germany.

[3] SANCHEZ J.A., POMBO I., ALBERDI R., ZQUIERDO B., ORTEGA N., PLAZA S., MARTINEZ-TOLEDANO J. (2010) *Machining evaluation of a hybrid MQL-CO2 grinding technology.* Journal of Cleaner Production. 18:1840-1849.

[4] KLOCKE F., BRINKSMEIER E., WEINERT K. (2005) *Capability Profile of Hard Cutting and Grinding Processes*. Annals of the CIRP. 54.2:22-45.

[5] KUNDRÁK J., KARPUSCHEWSKI B., GYANI K., BANA V. (2008) *Accuracy of hard turning*. Journal of Materials Processing Technology. 202:328-338.

[6] MAŇKOVÁ I., BEŇO J., MARKOVÁ G. (2008) *Contribution to hard turned and ground surfaces microgeometry evaluation.* Acta Mechanica Slovaca. 12.c4-a:85-92.

[7] ZĘBALA W. (2008) *Modeling of Cutting Process with Cooling.* Journal Advances in Manufacturing Science and Technology. Oficyna Wydawnicza Politechniki Rzeszowskiej. 4:73-81.

[8] ZĘBALA W. (2005) *Simulation of Cutting with the Defined Tool Geometry*. Journal of Machine Engineering 3-4:109-119.

[9] LUKOVICS I., BÍLEK O. (2010) *High Speed Grinding.* Proc. on the microCAD´2001 International Computer Science Conference, Section N, Production Engineering and Manufacturing Systems. Miskolc :207-212.

[10] VARGA GY. (2009) *Examination of Metal Cutting at Environmentally Friendly Machining.* Concurrent Product and Technology Development – CEEPUS Scientific Book. Croatia. :103-119.