

Sovilj, B. ,Tiba, SZ. ,Kovač, P., Ješić, D. , Sovilj-Nikić, I.

INFLUENCE OF COATING ON TOOL LIFE OF HOB MILLING TOOL

Abstract

The hob milling is most widely applied in the course of machining serration of the cylindrical gear due to the high productivity of the process.

The knowledge and investigation of the process of machining serration is of extreme importance for the manufacturers of the toothed gear.

On the basis of analysis of the complex process of cutting of cylindrical gears by hob milling and performed simultaneous investigation of uncoated and coated hob milling in production conditions, this paper presents the possible significant cost reductions by application of coated tools.

Key words: hob milling wear, tool life, feed, cutting speed, gear.

1. INTRODUCTION

The development of the production tools, special industrial and civil engineering machines on the one hand, and prime movers on the other has brought about the occurrence of different designs of the power gear and turning moment, with the prominence of toothed gearing.

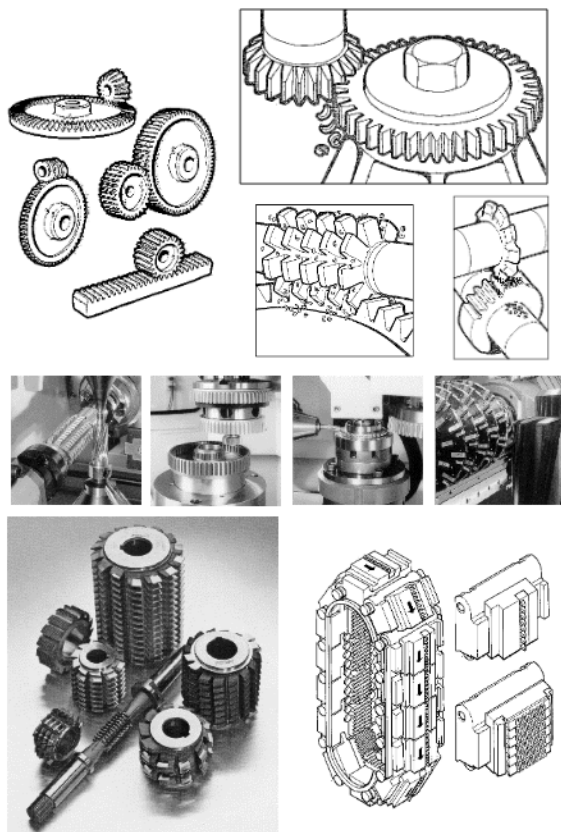


Fig. 1. The basic types and methods of serration, the basic and up-to-date tools for serration machining

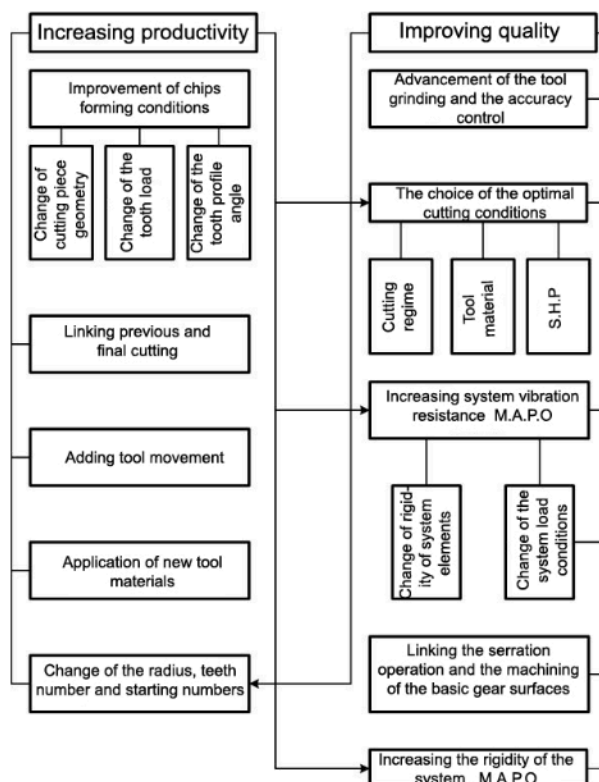


Fig. 2. Directions of advancement of hob milling gear serration

The problem of producing toothed wheel has been analyzed both in theory and practice in different ways; whereby the toothed wheel has been identified both as a part of a machine and as an element of production, that is a finished product.

The basic types and methods of serration, the basic and up-to-date tools for machining serration have been given in Fig. 1.

The hob milling is most widely applied in the course of machining serration of the cylindrical gear due to the high productivity of the process.

The knowledge and investigation of the process of machining serration is of extreme importance for the manufacturers of the toothed gear.

The hob milling process is one of the most important elements in the chain of gear mechanical machining, since productivity; final geometrical accuracy and quality of serration surface depend heavily upon it.

The improvement of the hob milling process is important and useful in the production of both toothed gear and hob millers. The directions of improvement of the hob miller serration are presented in Fig. 2.

The wear is one of the utterly negative occurrences in the machining processes. A relatively high pressure and high temperatures on the contact surfaces of the conjugated pairs, as well as the relatively high speed of the conjugated pairs are thought to represent the basic causes for the occurrence and intensive progression of the tool wear process. The wear of the working elements of the cutting wedge is continuous at all points of the process, as well as in all technological conditions and working regimes.

A distinction should be made between the tool wear and wear-out. The wear is a form of hob miller wear-out, because we can divide the causes of the wear-out, that is the loss of the cutting properties of the tool, as shown in Fig. 3, into four basic groups.

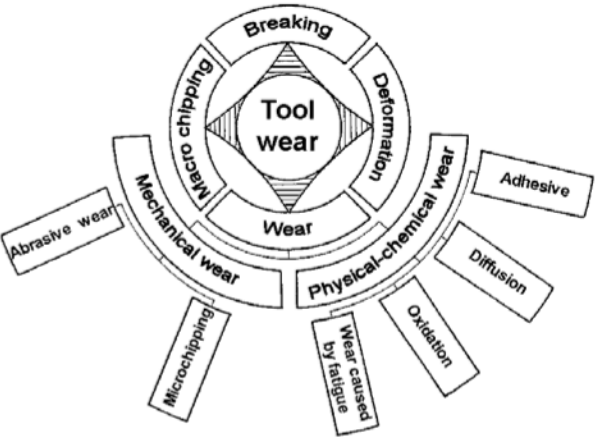


Fig. 3. The basic forms of the tool wear-out

The process economy of the hob milling depends first of all on the type of tool wear. A great number of values and their alternating influence impede the research into the process of wear.

The wear of a single hob milling machine tooth depends, inter alia, on the size of axial feed and a number of the feeds. The progression of wear on a certain hob milling machine tooth depends, as well, on the combination of tool and workpiece material, the machine and the coolant and lubricant used; it also depends on the machining parameters presented in Fig. 4.

Tool and workpiece geometry and the milling procedures influence the hob milling machine wear (Fig. 5). In order to estimate the tool wear, it is necessary to know which factors influence the process of hob milling; the degree of influence of particular parameters on the process itself is presented in Table1.

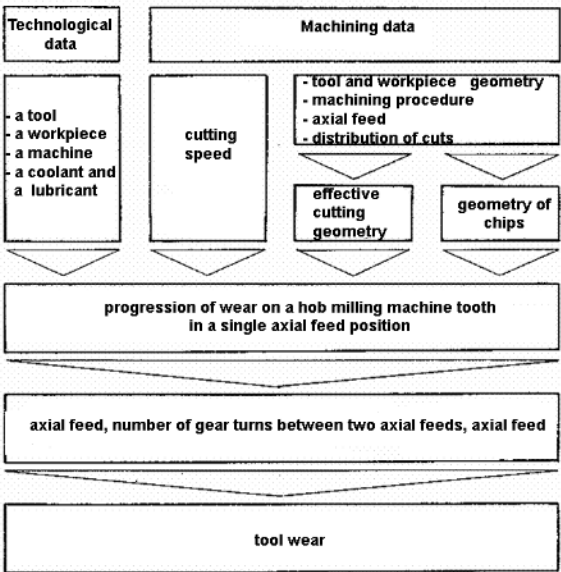


Fig. 4. Parameters influencing the process of the wear of hob milling machine

Tool geometry Workpiece geometry Hob milling procedures

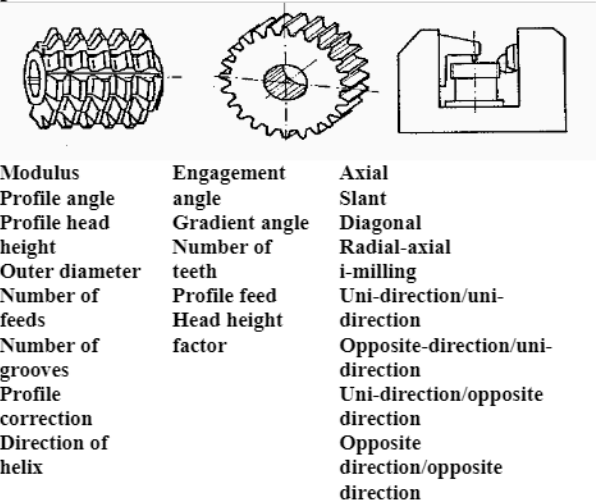


Fig. 5. Tool and workpiece geometry and milling procedures

Changeable influential factors		Conditions of cutting							Milling and cutting geometry					Materials		
		Cutting speed	Axial feed	Milling method	Milling procedure	Axial milling	Section distribution	Cooling conditions	Number of feeds - Z	Number of chaser teeth - n	Miller outer diameter - Dg	Rake angle γ	Clearance angle α	Profile correction	Workpiece material	Hob miller material
Characteristics of the cutting process		Chip length		o				o		o	o	x				
		Chip shape		o	x	o		o		o	o				x	
		Chip thickness		x		o		o		x	o				x	
		Compression		o	x	o	o			o	o	x		o	x	
		Detachment disruption		o						o				o	x	
Chip detachment	Layers on the cutting edge	x	o					o				o	o		x	o
	Effective clearance angle			x	o				x				x			
	Number of cuts		x			x	x		x	o						
Cutting process	Cutting time	x				o	x				o					
	Temperature	x	x	o					x	x	o		o	o	o	x

Table. 1. Matrix of factors influencing hob milling (x-significant impact, o-small or indirect impact)

Complicated kinematics and geometrical links between the tool and the workpiece cause a number of difficulties, which impede the utilization of the tool, tool machine, i.e. they impede the optimization of the whole process of cylindrical gear serration machining. The difficulties we have listed become evident through insufficient durability of high-speed steel hob milling machines.

Experts for cutting machining, process engineers and metallurgists from the world's industry and science have been for many years attempting to reduce the high speed steel tool wear, in order to increase the economy and overcome the differences between tools made of high speed steel and tools made of hard metal.

For the last thirty years a considerable advancement has been made in creating new tool materials, new tool designs, in heat-treating and automatization of the machining process. Further research has been directed towards the problem of how to improve the surface of the tool for machining cutting.

Nowadays, parts and tools for machining cutting are more frequently made of composite materials; the core of these materials serves to ensure the hardness and rigidity while the surface layers serve as rust preventives, wear preventives; they have to meet optical, esthetical, heat-treat and electrical demands. Such materials can be produced by using different coating techniques. The importance of these technologies is characterized by a fact that by coating them with thin layers we can ensure that they bear the required load on the one hand, and that we economize with the basic material on the other.

On the basis of the analysis of the linkages among all the participants in the coating process (Table 2.), the need to inform the tool manufacturers about the specific additional requirements of coating their tool with materials having wear proof properties becomes evident.

Tool manufacturer	Tool coating	Tool user
Specialized in:	Coating department, Setting the PVD center for coating Distributor	The automobile and tractor industry recognizes the benefits of advantages of the coated tools
- tool design, - tool manufacture, - tool material		
Lacks knowledge in:		
- plasma physics, - highvacuum technique, - thin coats, - surface physics		-greater speed and feed -greater durability -better quality -shorter processing time
However:		
he has been asked to supply the coated tools		Therefore: Ask them to supply the coated tools

Table.2. Linkages among all the participants in the process of coating and their skills

2. EXPERIMENTAL RESEARCH

The increasing demands set for cutting machining tools require that new methods for making composite materials are constantly found and developed. Especially developed are the procedures of coating with hard material with the aim of wear prevention; the use of these materials in industry has been withheld because of the lack of knowledge and experience.

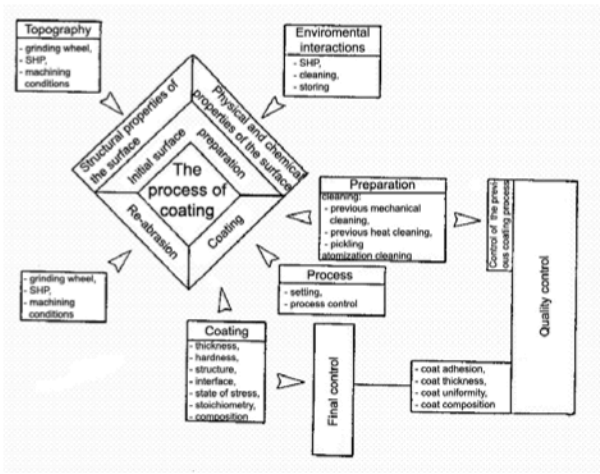


Fig. 6. Parameters influencing the tool coating

Data about the coated tools are not widely known probably because of the short period of their use, and every single case has to be carefully studied.

In order to clarify the possibilities of using the coated hob milling machines in industry, experimental research on the coated and uncoated tools should be performed, both in laboratories and in production. This paper presents a fragment of the results of the comparative study performed in real production conditions.

On the basis of data we have gained we can say that durability of new coated hob milling machines is three or four times greater than those of the uncoated. It neither means that the coated hob miller wears three or four times less for the same quantity of the machined parts, nor that it will produce three or four times greater number of parts for the same blunting between two sharpenings.

Criterion used in this research was the ratio of machined parts, under the same cutting regimes for coated and uncoated hob milling machines in the exploitation period of the two comparative tools for machining cutting. It is clear that we refer to the machining of the same parts on the same serration machine. We should not allow the same degree of wear for the coated and uncoated milling machine in our experience. The reason is a different ratio of the wear zone c and wear height h , meaning that the rounding of the acrons of the cutting edges is different.

The comparison shown in the Fig. 7 can be applied when the coated milling machine tooth face has been sharpened and used. Tooth-faces of both hob-milling machines are in that case uncoated, and on the coated tool tips and laterals have been previously coated with a thin protective layer. Owing to this, the wear zone of the coated miller- c_0 increases more slowly

than the wear zone of the uncoated miller- c_n , with respect to the wear height h . The magnified wear is presented in Fig. 8.

It is clear that the coated layer, wear resistant, protects the basic tool material. Our current observations are still in the range of looking for the starting point of high degrees of wear, which depends on the value of wear height h and the feed, i.e. the zone which is being worn. This has been experimentally proven for a great number of times.

The experiments have been conducted in the following way: Our experience tells us that

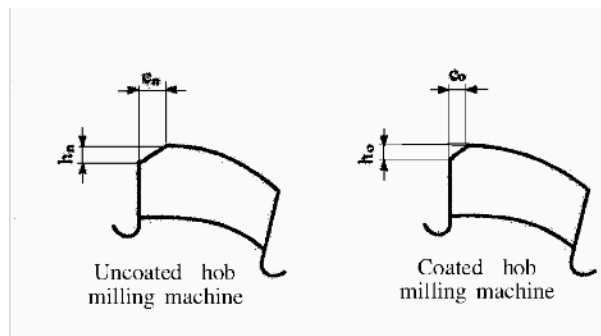


Fig.7. Differences between ratios and rounding of the acrons of the cutting edges of the uncoated and coated hob milling machines

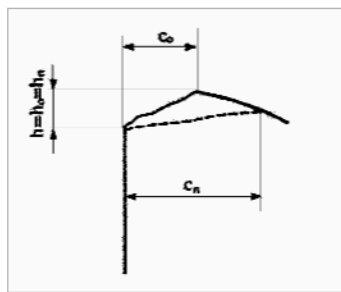


Fig. 8. The wear zone with the uncoated and coated hob milling machine

the hob milling machine can machine N pieces in certain cutting regimes. If the axial feed of the hob milling machine is four times greater than the usual, the tool will machine four times smaller number of pieces while going from one end to the other. The wear, which occurs, is small. By repeating the number of “passages” and by determining the wear we get the experimental points which make it possible to draw the process of wear, so that we can determine the point which is followed by the third wear phase. Entering the third wear phase is a pointer that the machining process, in the chosen cutting regimes, has to be terminated. It would be possible to continue with the machining serration process only if we increase the feed, i.e. if we increase the engagement area which prolongs the second phase of wear. The height wear h for the increased feed is no longer critical and in that case phase III shifts towards a greater number of machined parts. The reason is clear: the worn cutting edge cannot get through the thin coat, and instead of cutting the material, it kneads it, which is a cause of great wear. By increasing the feed, we enable the worn cutting edge to work on the thicker layer and it still cuts the material; it

does not knead it. In this manner, although we increase the feed, we can postpone the starting point of the third phase of wear. By doing this we wanted to determine the extent upon which the critical point depends on the chosen, that is applied feed.

According to the research conducted in IMT, the most frequent cases correspond to the ratios given in Figure 9. The amount of the machined pieces for a durability are in ration 3 to 4, in favor of the coated hob milling machines, and the degrees of wear are in ration 1,5 to 1, again in favor of the coated milling machines. If we take that the wear of the uncoated hob milling machines is 50% greater and that we should not give an exact value of wear, there is one more advantage in favor of the coated hob milling machines. If we take as an example the average acceptable wear in IMT, it is $c_n=0,6\text{mm}$ for uncoated tools and $c_o=0,4\text{mm}$ for the coated ones; the ratio of the maximum wears is $0,6:0,4=1,5$. If we know that there are traces of the wear of $0,05\text{mm}$ on both of the hob milling machines, which have been observed and sharpened, then the ratio will be $(0,6-0,05): (0,4-0,05)=0,55:0,35=1,571$, so that we get 7%. Someone may think this is a rather small percent; however, if we know that costs of purchasing hob milling machines are very high, these 7% must not be disregarded.

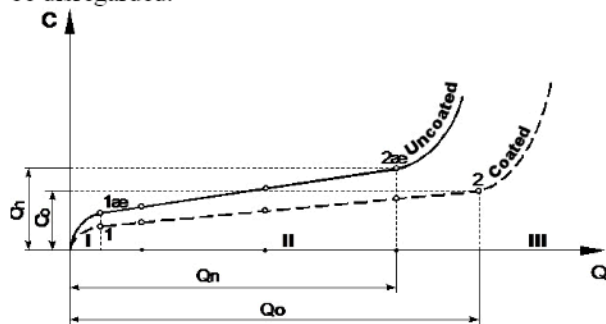


Fig. 9. Progression of the wear process for the uncoated and coated hob milling machine

If we consider the previous 4:3 advantage of the coated milling machines and if we apply it in economical sharpening of 1,571, then the equation will be:

$$4/3 \times 1,571 = 2,095$$

To this we should add a smaller number of slowdowns due to the tool replacement, which was done in every 6 hours for the uncoated and every 8 hours for the coated hob milling machines, it is obvious that we lose half an hour in every 6 hours for the uncoated hob milling machines and as much in every 8 hours for the coated ones. Then we have $0,5:6=0,0833$, and $0,5:8=0,0625$, that is, instead of 8,33% we lose 6,25%. The difference is 2,08%; it refers to the machine and is very significant. Because of the previous method of payment we cannot talk about the increase of the harshness of the regimes for hob milling machines in percents; it would also mean that less work and energy would be needed, the tool life would be longer for the same production and there would be more time for proper maintenance.

Unfortunately, neither science nor modern equipment can give good results unless there is a

proper use of hob milling machines and unless we get a proper feedback from the factories.

3. CONCLUSION

On the basis of the analysis of the complex process of serration machining of the cylindrical gear by hob milling and conducted comparative investigation of the uncoated and coated hob milling machines in IMT, a conclusion has been reached that significant savings can be made by using the coated tools.

The hob milling process is one of the most important elements in the chain of gear mechanical machining, since productivity, final accuracy and quality of the gear depend heavily upon it. One of the basic cutting parameters, which influences the machining time and process economy, is the feed. The increase of feed has a less significant influence upon the wear increase than the increase of cutting speed.

REFERENCES

- [1]. Barrov, G. : Wear of cutting tools, Tribology, 5, No.1, 1972.
- [2]. Ivkovic, B. : *Tribologija rezanja*, Gradjevinska knjiga, Beograd, 1979.

- [3]. Kelly, W. D. : Gear cutting with TiN - coated tools, American machinist, 1982.
- [4]. Sovilj, B. : *Identifikacija triboloskih procesa pri odvalnom glodanju*, Disertacija, Fakultet tehnickih nauka, Novi Sad, 1988.
- [5]. Sovilj, B., Radonjić, S., Sovilj-Nikić, I.: *Analysis of application of profiled tools for serration in "Kolubara-Metal" factory*, Journal of production Engineering, Volume number 12, No.1, pp.75-78, 2009.
- [6]. Stanic, J. : *Teorija obrade metala I*, Masinski fakultet, Beograd, 1986.

Authors: Prof. dr Bogdan Sovilj, Prof. dr Pavel Kovač, Ivan Sovilj-Nikić,, Univerzitet u Novom Sadu, Fakultet tehnickih nauka, Trg Dositeja Obradovića 6, 21000 Novi Sad, Srbija, FAX: +38121458133, TEL: +38121450366, **D.Sc. Eng Zsolt TIBA,** University of Debrecen, Faculty of Technical Engineering, Department of Mechanical Engineering, Debrecen, Hungary, **Dr Dušan Ješić,** Tribotehnik, Rijeka, Croatia

E-mail: bsovilj@uns.ac.rs
tiba@mfk.unideb.hu
dusan.jesic@ri.htnet.hr