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ENVIRONMENT-FRIENDLY CUTTING OF CYLINDRICAL GEARS

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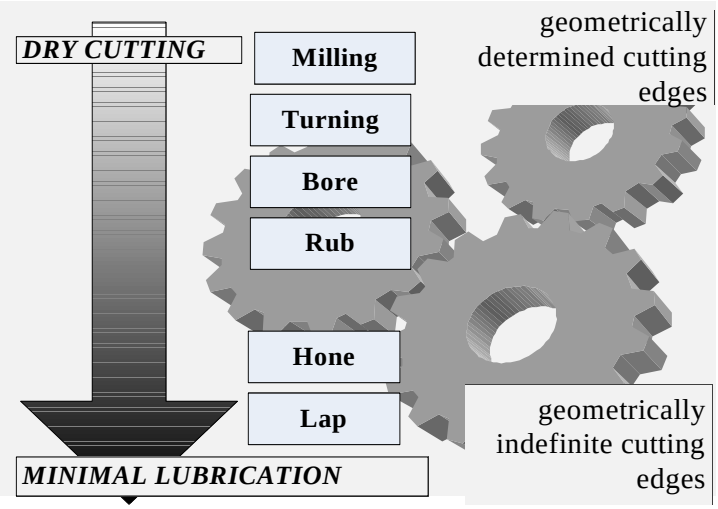
ABSTRACT
One of the main sources of environmental pollution during the machining processes is the huge amount of supplied cutting fluids. To avoid the problems caused by use of cutting fluids, considerable progress has been made in the last years in the field of near–dry machining. The conversion from conventional lubrication- cooling processes to minimal quantity lubrication methods demands new tasks classification in the tribological system in order to guarantee the process safety and product quality. In the paper the authors presents their theoretical and practical researches in the field of cylindrical gear milling using several kinds tools, lubrication and cooling methods, in order to evaluate the effects of some environment-friendly techniques.
Keywords: Near-dry cutting, gear milling, environment-friendly processes

1. INTRODUCTION TO NEAR DRY CUTTING

1.1. Near dry cutting as a part of green manufacturing
During actual period an advanced manufacturing mode – Green Manufacturing (GM) - is critically required for sustainable development process. In this sense modern machining processes face continuous cost pressures and high quality expectations. During the machining processes the cutting fluid is one of the main sources of environmental pollution. How to minimize the environmental impact of manufacturing systems related to cutting fluids is one of the important issues in the field of GM. Different types of cutting fluids employed in the manufacturing process have different impacts on the environment. The three objectives of quality, cost, and environmental impact are the critical factors, which should be integrated into cutting fluids selection for GM [2].
Machining technologies have been continuously developed aiming at getting the higher productivity and precision in manufacturing processes. Cutting fluids have been widely used to achieve these purposes, their action of cooling and lubrication, and to play a significant role in successful machining operations. Concerning the environmental issues, such ozone layer depletion, the global warming effects, and environmental pollution, it has nowadays raised the importance of environmentally friendly manufacturing. To avoid the above mentioned problems, caused by cutting fluids, considerable progress has been made in the last years in the field of dry and near-dry machining (NDM). In particular, machining with minimal quantity lubrication (MQL) has been accepted as a representative near-dry application because of its environmentally friendly characteristics.

1.2. Technical features of MQL and NDM in the practice
The large number of studies has demonstrated that it can prove the satisfactory outcome in many practical machining operations (Fig. 1). Concerning the cutting lubricants properties for MQL they should be selected not only on the basis of its primary characteristics (cutting performance) but also by reason of its secondary characteristics, such as biodegradability, oxidation stability, storage stability, and water-soil-air pollution. Although the tribological action of a very small amount of lubricant is certainly of



great significance in MQL machining, it should be also considered the relationship between MQL cutting performance and the tribological behavior of lubricants.

The conventional use of coolants/lubricants costs a lot of money and is hazardous to health and the environment. As mentioned before it could avoid this by introducing clean manufacturing technology. This allows at the same time the increasing of process productivity, thus securing itself the competitive advantages of tomorrow.

Figure 1. Cutting process accomplishing with ecological methods

The main feature of NDM with MQL is the replacement of the flood coolant with a very small amount of mineral or synthetic oil, which is applied directly and in a precisely dosed manner at the cutting point. With the introduction of this residual-free consumption lubricant, the manufacturing costs will decrease considerably, because the high costs for the preparation and removal of emulsion can be avoided. In addition, the costly health and environmental problems associated with the use of coolant lubricants are avoided as well.

Cooling the work piece with emulsion is replaced with a strong reduction in heat from friction due to effective lubrication of the cutting area. Depending on the type of processing, is consumed between 6 and 100 ml/processing hour of the corresponding lubricant. The considerably improved lubrication of the machining area creates the possibility to operate the tools at much higher cutting speeds and feed rates. In this way it is not only possible to obtain an enormous increase in productivity, but also longer tool service lives and better surface quality of the products. The dry chips can then be recycled without incurring large cleaning expenses.

In order to appreciate the efficiency of near-dry techniques' application several technological tests have been done with recording of the essential effects. Some of them are: machining results (geometrical surface quality, precision), effectiveness of manufacture (wear tools), cutting forces and energy consumption, temperature of work piece and tool as well, process safety (edge-holding property, chips breaking, chips shape), pollutant emissions, vibrations level of tool/ work piece/ and machine tool and process.

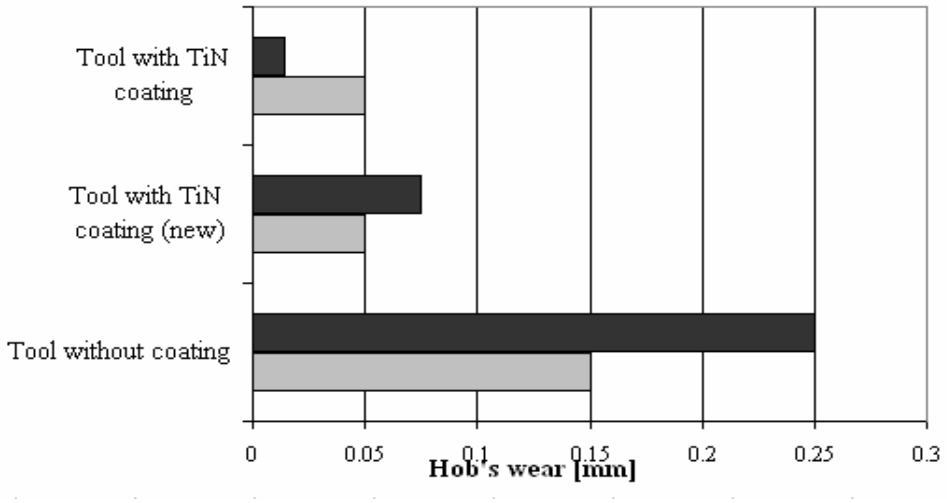
2. ENVIRONMENT-FRIENDLY TECHNIQUES AT GEAR HOB MILLING

The flood coolant cutting is still far common with hobs. Particularly in small-batch manufacturing with small numbers of items and in the gear machining from middle to large gear wheel modules with cemented carbides tools the flood coolant cutting is not to be excluded. The positive effects and the tools the available let no doubt about the sense of the flood lubrication cutting arise for many years.

The advantages of flood lubrication can't compensate their disadvantages, so that MQL technology is a favorable alternative also to hobs. In this case changes arise regarding the size of the working forces, temperatures and in wear characteristics in relation to the full jet technology primarily, while all sizes remain constant. Researches presented in this paper were concentrated on the technical evaluation and the effect of these above mentioned parameters at the milling process of the gears. with the following parameters: modulus- 2,75 mm, number of teeth - 37, diameter-ϕ110 mm, teeth breadth - 19 mm..

2. 1. Influence on the hob's wear

The complete instrumentation were supervised within the attempt program: the development of the work piece and tool temperature before and after milling, the force behavior, the wear characteristics of the assigned tools, the behavior of the tooth wide as measure for the tooth thickness of the gear wheels and the behavior of further teeth deviations. Hob's tool life has a decisive influence on the cutting process effectiveness. It was used during the experimental investigations a tool from Mo5Co5 with TiN - coating.



The results are represented in the figure 5 and they show that with the employment of the MQL technique gained favourable wear/ tool life, which are attributed causally to the outstanding lubricating action of the assigned lubricant.

Figure 2. Average values of the hob's wear

To comparison purposes dry cutting was also use. Here a very unfavorable employment behavior showed up. After cutting of few work pieces the attempt had to be broken off. The wear effect by the hob reveals itself by the upward gradient of the machine cutting forces and the temperatures.

2.2 Consequences on surface quality

With increasing, in particular abrasive wear it is added as a rule that with the gear milling process in the effect place an increased supplemental work must be carried out. This leads both to a rise of the shear forces and to the increase of the temperature in the effect place and concomitantly at the cutting edge and at the work piece. The effect of the temperature higher with the DC and/or the MQL on the quality of gear teeth is shown in the figure 3.

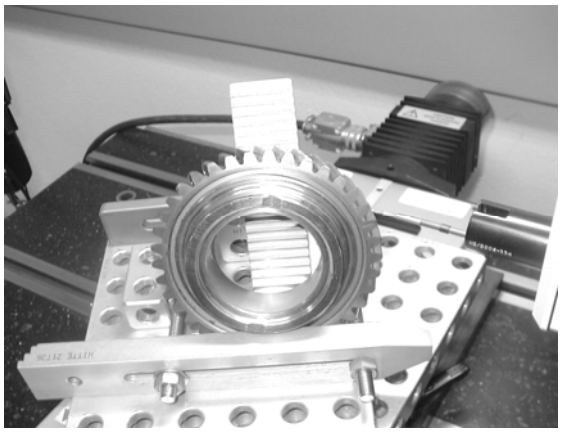


Figure 3. Tooth surface roughness measurement

A comparison of the roughness values of damage-free milled teeth profiles of the standard attempt gear wheel furnished the result represented in the diagram 4 for the employment of the flood cooling (FC), minimal quantity lubrication (MQL), minimal quantity cooling (MQC) and dry cutting (DC) for a generally coated hob (Fig.4). This comparison is for the MQL very satisfyingly.

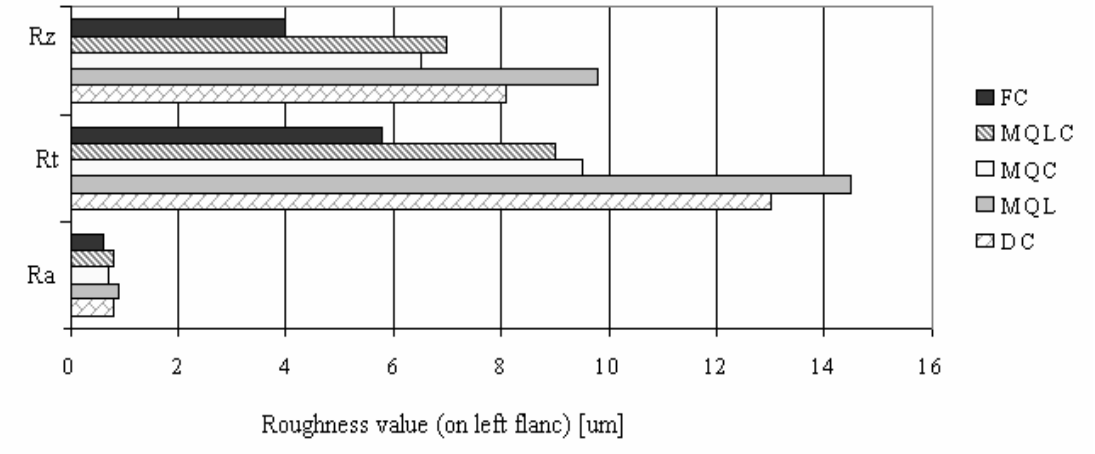


Figure 4. Measured roughness values

2.3. Pollutant emissions to gears milling with MQL

The following researches demonstrated despite the emissions gave-off by MQL, the application of this technique doesn't have unfavorable effects on the environment. The DC, where cooling/ lubrication/ and wash effect are realized through alternative measures, seems to be the ideal method from ecological point of view. For analyzing of the air volume was used one special device Multigasmonitor Typ 1301(Fig.5).

The air samples were collect during the milling process of the gears. Evaluation of the emissions generated during the manufacturing of the gears was made by a quantitative comparison between the measured values from DC, MQL, FL and MWC (Maximal Workplace Concentration) / TAC (Technical Admissible Concentration) values. The Multigasmonitor 1301 device is able to detect and analyze 42 pollutant gases. From all these only the following 6 appear by manufacturing of the gears wheel in the above-mentioned conditions: acrylnitril (C_3H_3N), diclorehtan ($C_2H_2Cl_2$), dimetilamine (C_2H_7N), nitrogen cyanide (HCN), sulphurdioxide ($S0_2$), vinilcloride (C_2H_3Cl). It shouldn't be excluded the assumption that the presence of acrylnitril and dimetilamine in the released emissions is the consequence of the high temperature developed in the cutting zone by MQL and DC.

The concentrations of diclorehtan and hidrogencyanid haven't been influenced by the cooling or lubrication methods, them appearance is caused by the sensibility to the presence of other gases in the analyzed air-volume. Similarly, the big concentration of sulphurdioxide is the consequence of the presence of the water vapors in the atmosphere. Analyze of air samples composition demonstrate the fact that despite the emissions by MQL, the application of this lubrication method hasn't any pollutant effect. The obtained results prove that the DC is an ideal process from ecological point of view.

Figure 5. Multigasmonitor 1301

3. CONCLUSIONS

MQL represents itself a viable alternative for gear milling with respect to tool wear, heat dissipation, and machined surface quality. This research compares the mechanical performance of MQL to completely dry lubrication for the milling of small modulus gear based on experimental measurement of cutting temperature, cutting forces, tool wears, surface finish, dimensional deviation and air pollution. Some of results have been presented in this paper and indicated that the use of NDM leads to reduced tool wears, surface roughness, and environmental pollution.

Practical experiences show the fact that it can do in numerous cases without the use of lubricant completely or with a small quantity of lubricants and so a higher economy can avoid industrial safety-technical and environmentally referred problems. In addition the possibilities and borders of the employment of DC MQL, with almost dry splinters result, it must admit too. With same productivity like conventional use of coolants and lubricants, clean technologies are a competition advantage for tomorrow.

4. REFERENCES

[1] Rahman, M; Kumar A.S. & Salam M.U.: Experimental evaluation on effect of minimal quantity lubricant in milling. International Journal of machine Tools & Manufacture 42 /2002, 539-547 pp.,

[2] Tan, X.C.; Liu, F. et al.: A decision-making framework model of cutting fluids selection for green manufacturing. Journal of Material Processing Technologies 129/2002, 467-470 pp.,

[3] Weinnert, K., Inasaki, I., Sutherland, J.W., Wakabayashi, T.: Dry Machining and Minimum Quantity Lubrication. Annals of the CIRP Vol. 53/2. 2004 Keynote Paper.,

[4] Wessel, G.: Technologiesprung von der Minimalmengeschmierung zur Trockenbearbeitung beim spanabhebenden Trennen. Fertigungstechnisches Seminar- Fachhochschule Wedel, 2001,

[5] Fratila, D., Gyenge Cs, Ros O.: Near-dry Machining - A Modern Way for reducing the ecological impact of the cutting processes. 18th International DAAAM Symposium, 24-27th October 2007, Zadar, Croatia. (ISTP/ISI Proceedings and ISTP CDROM/ ISI Proceedings)-2007. ISBN 3-901509-58-5, ISSN 1726-9679. p. 289-290.