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INFLUENCE OF COOLING AND LUBRICATION ON SELECTED FEATURES OF GEOMETRICAL STRUCTURE OF SURFACES TURNED AT HIGH CUTTING SPEEDS

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Abstract

The article presents research results on the influence of cooling and lubrication of the cutting zone as well as an impact of cutting parameters on the surface roughness and material bearing ratio of the roughness profile of a turned 18G2A steel surface. The goal of the research was to determine effects of elimination or reduction of a cooling and lubricating fluid in the process of high speed turning. It has been concluded that in high speed machining conditions, the influence of the used modes of cooling and lubrication in the cutting zone is limited. Eliminating or reducing the quantity of the cooling and lubricating medium in the process of turning does not cause worsening of the geometrical characteristics of a machined surface which, together with environmental reasons, makes dry/MQL machining highly justifiable.

Keywords*: cutting, cooling, lubrication; dry cutting; surface roughness*

1. Introduction

Cooling and lubrication of the cutting zone have a considerable influence on the longevity of tools' cutting edges, dimensional accuracy, characteristics of the surface layer of machined pieces as well as shaping conditions and chip removal from the cutting zone. Because of high costs of cooling and lubricating fluids, their impact on the environment and on machine operators' health, the machining industry more and more often prefers machining without such fluids. This is called dry machining or machining with a minimal quantity of lubrication (MQL machining) [1,3-5,8]. This is further encouraged by the development of tool materials and coatings, and new designs of tools and machining devices. Unfortunately, strict requirements related to dimensional and shape accuracy as well as to surface roughness accompanied by a strong feeling that cooling and lubrication fluids are absolutely necessary effectively block a more widespread use of such machining methods. Their popularity requires an in-depth knowledge of the machining process and optimal cutting parameters for particular materials [7,11].

The need to reduce costs and increase overall manufacturing efficiency caused that high speed machining (HSM) is becoming more and more popular in the industry, especially because machining time constitutes a significant part of the total manufacturing time. There are several definitions of high speed machining. An important factor that allows to regard a particular value of

the cutting speed as high speed machining is a type and characteristics of the machined material [6]. This type of machining has many advantages: high efficiency of removing machining allowance, higher quality of the machined surface, shorter manufacturing time, decreased cutting force, more effective thermal energy transfer through chip removal, decreased deformation of the machined piece and others [10,11,12].
The fact that comparative studies into the influence of cooling and lubrication modes on the geometrical characteristics of surfaces machined at high cutting speeds are far and between justifies the presented research. Its primary aims were to determine the influence of eliminating the cutting fluid (dry machining) or reducing its quantity (MQL) on selected characteristics of the geometrical structure after turning 18G2A steel and to compare these values with those after machining with emulsion.

2. Experimental procedure

The research was performed on a CNC turning machine made by A. Monforts Werkzeugmaschinen GmbH & Co, type RNC 400 with the primary drive of 18,5 kW. The machined piece (turned longitudinally) was a pipe made of 18G2A construction steel of higher quality, 75 mm in diameter with a wall thickness of 10 mm and a length of 150 mm. The pipe had 10 mm measurement zones. The choice of steel was dictated by its narrow limits of carbon and manganese content as well as low quantities of impurities, mainly silicon and phosphorus. The chemical composition is shown in table 1.

Tab.1. Chemical composition of 18G2A steel (PN-H 74245:1996)

C	Mn	Si	P	S	Cr	Ni	Mo	W	V	Al.	Cu
0,2	1,5	0,2-0,5	max 0,04	max 0,04	max 0,03	max 0,03	-	-	-	max 0,2	max 0,3

The following modes of cooling and lubrication were used:
-S – no cutting fluid, dry,
- MQL – minimal lubrication with oil fog quantity of 0,014 mm^3/s,
-E – 14% cutting fluid, based on Super Oil EP emulgating oil by Oilcom, designed for steel and cast iron machining with a 0,07 dm^3/s flow,
The oil fog was made from Acu-Lube LB8000 vegetable oil with a Minibooster MBII device by Acu-Lube (fig.1).

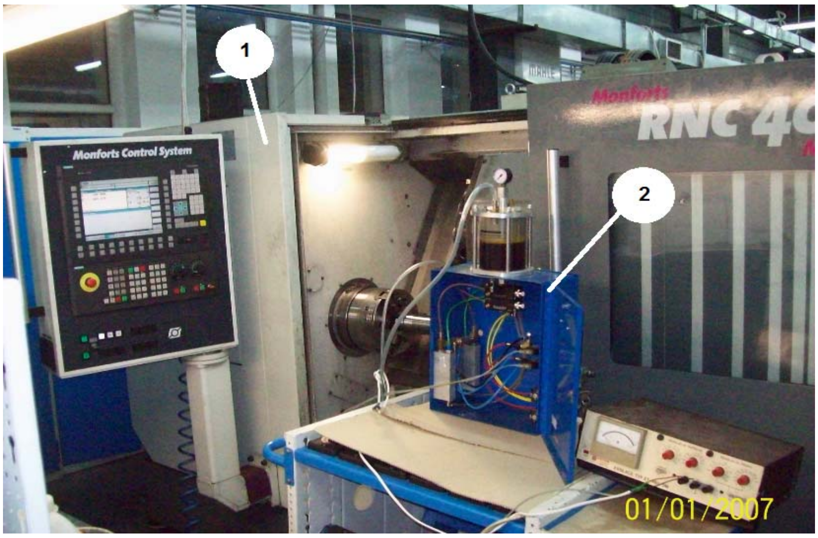


Fig. 1. Workplace, 1- machine, 2- Minibooster II oil fog generator

The cutting tool used in the research was MSS 2525–12-EB produced by Mikrona, with oil fog access channels and interchangeable SNMG 120408TF cutting edges by ISKAR. The edge geometry: $\gamma_0=5^0$, $\alpha_0=10^0$, $\chi_r=45^0$, $\lambda_s=0^0$, $r_\varepsilon=0{,}8$ mm, covered with TiAlN and TiN coating by means of the PVD method.

The turning tests were performed with a complete static program [9] with changeable cutting speed and feed with three value levels and a permanent cutting depth a_p 1 mm. The values assigned to the cutting parameters are presented in table 2.

Tab. 2. Working conditions

sample No	1	2	3	4	5	6	7	8	9
v_c m/min		418			511			581	
f mm/rev	0,08	0,15	0,30	0,08	0,15	0,30	0,08	0,15	0,30

The analysis of the influence of cooling and lubrication modes in the cutting zone on the geometrical structure of the machined surface was performed based on measurements of the *Ra* parameter and material bearing ratio curves of the surface roughness. The measurements were made on a Hommelwerke T2000 profilographometer, with a M1 DIN-4777 filter and a TK300 sensor with the following parameters: measuring range: 20 µm, measured length: 4,8 mm, elementary measuring length: 0,8 mm, measuring speed: 0,50 mm/s. The measurements were repeated 5 times and mean values were calculated.

3. Results and discussion

The results shown in fig. 2 reveal a significant influence of the cooling and lubrication modes of the cutting zone on the measured characteristics of the geometrical structure of the machined surface, which depended on the employed cutting parameters. In turning at a low feed rate (*f*=0,08 mm/rev), the influence of cooling and lubrication on the surface roughness was limited. Eliminating the emulsion led to slight decrease of the *Ra* parameter value, compared with turning with emulsion whereas the application of MQL resulted in the lowest value of the surface roughness (*Ra*=0,37 µm). Along with an increase of the feed rate, the diversification of the *Ra* value increased, depending on the cooling and lubrication mode with the relation of the interaction between the conditions of cooling and lubrications maintained. The greatest differences in the values of the *Ra* parameters, depending on the cooling and lubrication in the cutting zone, appeared in turning at a feed rate of *f*=0,30 mm/rev. The limited diversity of the surface roughness values, depending on the cooling and lubrication mode, may have resulted from hindered access of the emulsion/oil fog to the cutting zone at high cutting speeds [4,6]. The lowest values of the *Ra* parameter after MQL turning may have come from decreased friction between the moving edge and machined piece surfaces and better conditions of chip creation and removal. The increased roughness after turning with emulsion, compared with dry turning may have resulted from the cooling action of the emulsion which decreased plastic properties of the material with the decrease of the temperature.

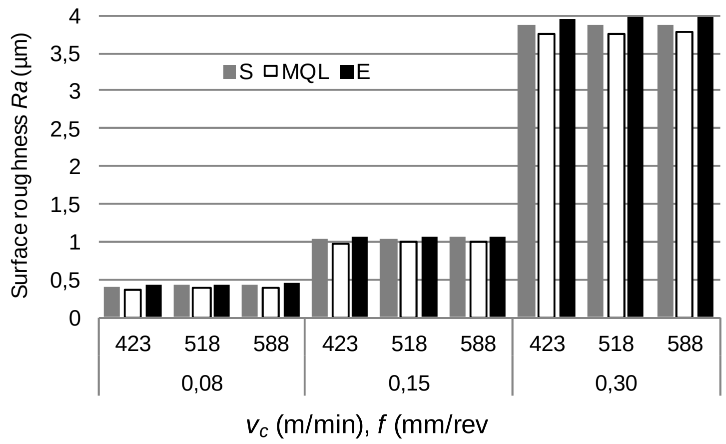


Fig. 2. Influence of cooling and lubrication mode surface layer roughness

Out of all the cutting parameters, the greatest influence on the increase of the *Ra* parameter was exerted by the feed rate (fig. 3). The relations between the cooling and lubrication mode and the surface roughness as the feed rate increased showed that the increase in the *Ra* parameter value was conditioned by kinematic-stereometric impression of the cutting edge on the machined surface. The influence of the cutting speed on the surface roughness when the speed changed from 423 to 581 m/min was insignificant, which points to relatively comparable cutting conditions in the used range of cutting speeds.

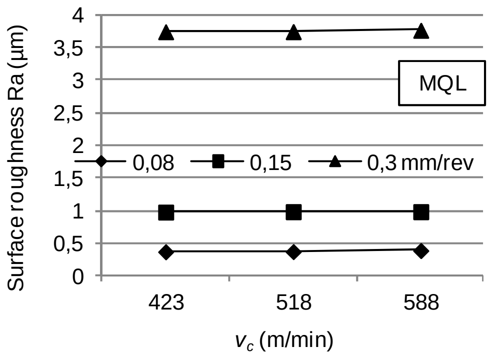
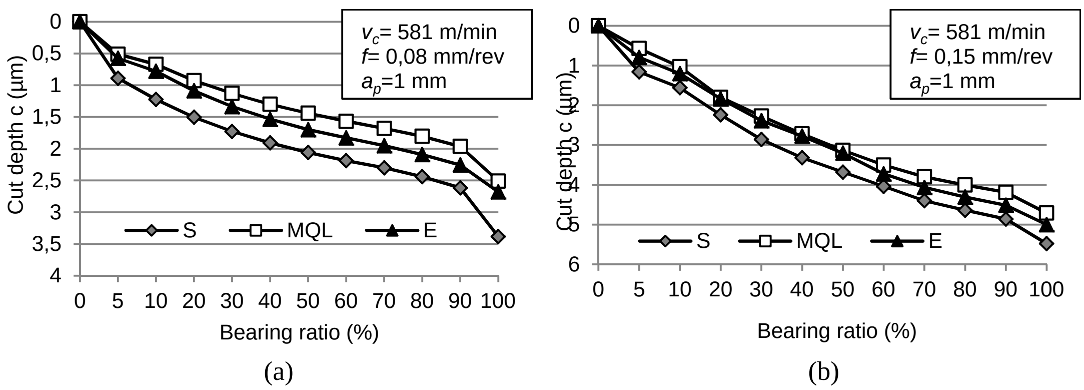
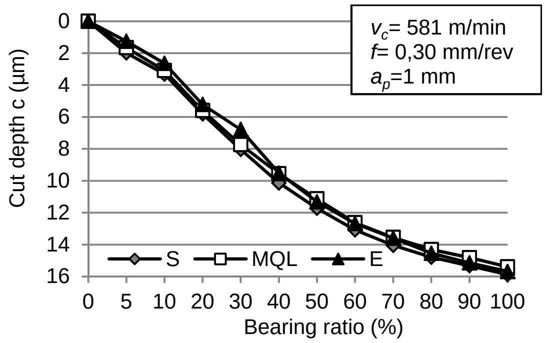


Fig. 3. Influence of cutting speed and feed rate on surface layer roughness in MQL turning

The material bearing ratio is also of great importance due to functional characteristics of the machined surface [2]. The performed research did not reveal any significant influence of the cooling and lubrication mode on the bearing ratio curves and bearing ratio itself in the used range of cutting parameters (fig. 4). Only after turning at a speed of 581 m/min and a feed rate of 0,08 mm/rev (fig. 4a) was it clearly observed that the Abbot-Fireston curve became more diversified. The greatest bearing ratio was observed in surfaces machined in the MQL mode. The height of the roughness profile above the roughness core was smaller than that after turning dry and with emulsion. This points to a greater resistance of the surface layer to wear. A similar shape of the Abbott-Fireston curve was observed after turning with emulsion. The surfaces machined dry had a lower material bearing ratio than the ones mentioned above. The heights above and below the roughness core were greatest and pointed to a lower resistance to wear as well as a greater ability to hold fluid in micro pits below the roughness core. With an increase of the feed rate, the bearing ratio of the machined surfaces decreased and the differences in the shape of the Abbott-Fireston curve became less obvious.

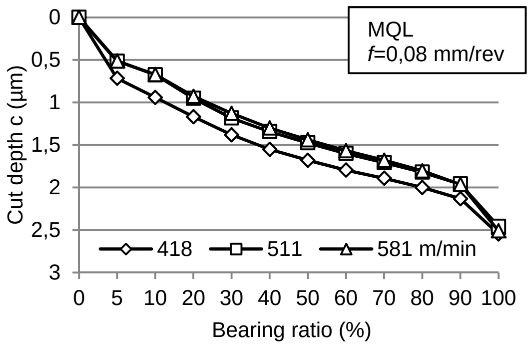




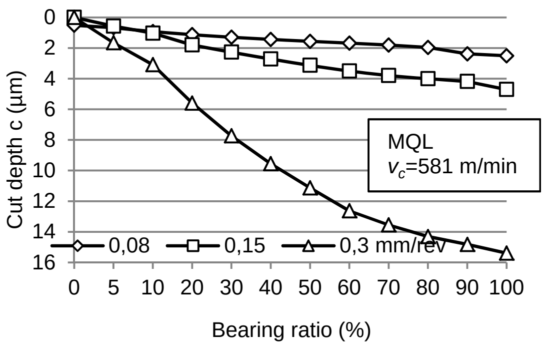
(c)

Fig. 4. Influence of cooling and lubrication mode on bearing ratio curve, (a) f=0,08 mm/rev; (b) f=0,15 mm/rev; (c) f=0,30 mm/rev)

The research showed that in the used cooling and lubrication conditions of the cutting zone, the influence of the cutting speed and feed rate on the Abbott-Firestone curve and bearing ratio was similar. The cutting speed did not significantly influence the bearing ratio. An increase in the feedrate caused the Abbott-Firestone curves to diversify in terms of their shape and bearing ratio, which became worse. The dependence of the bearing ratio of the machined surface on the cutting speed and feedrate in MQL turning is presented in fig. 5.



(a)



(b)

Fig. 5. Influence of cutting speed (a)and feed rate (b)on bearing ration curve of roughness profile after MQL turning

4. Conclusions

The performed research has revealed that the influence of the cooling and lubrication mode on the geometrical structure of surfaces machined at a wide range of cutting speeds is limited and depends on the used cutting speed and federate values. This may result from hindered access of the cooling and lubricating medium to the cutting zone.

In the used range of cutting parameters, the lowest roughness value was observed on surfaces machined in the MQL mode, after dry turning and finally after machining with emulsion. As the feed rate increased, the action of the cooling and lubricating medium increased as well. So did the differences in the roughness values, depending on the cooling and lubricating mode.

The greatest influence on the surface roughness was exerted by the feed rate whereas the influence of the cutting speed on the same parameter was insignificant.

The research did not prove and significant influence of the cooling and lubrication mode on the Abbott-Fireston curve shape nor on the bearing ratio in the used range of the cutting parameters. A greater value of the bearing ratio, compared to other cooling and lubrication modes, was recorded for MQL turning and turning at a speed of 581 m/min and a feed rate of 0,08 mm/rev. The cutting speed did not influence the bearing ratio, which became significantly lower as the feed rate increased.

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