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EFFECT OF CUTTING FLUID ON CHIP FORMATION AND MORPHOLOGY OF CHIP SURFACE DURING MILLING

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Abstract: Machining of metals and their alloys is often performed with the application of cutting fluids. The aim of their application is to reduce the temperature at the site of incision, which in many cases has a negative impact on the durability of the cutting edge of the tool and of its service life. The purpose of cutting fluid is to create a coherent and sufficiently resistant layer of lubricant, which reduces the negative abrasive, adhesive and diffusion effects occurring between the tool and the workpiece during machining. The method of application of cutting fluid at the incision site in terms of the direction of flow, volume and intensity also has a significant impact on the stability of the cutting process and the final quality of machined surface. Article deals with experimental research of the effect of changing the concentration of cutting fluid JCK HBs + H_2O, based on an oil-water emulsion, on the surface morphology and the chip formation in the face milling of the structural steel EN C45 (STN 12050).
Keywords: Machining; Milling; Cutting fluid; Surface Morphology

1. INTRODUCTION

Currently, there are high requirements placed on cutting fluids in terms of ensuring the stability of the machining process and achieving their optimum operational life. [2,6] An important task of cutting fluid is its cooling effect, especially since the temperature affects the tool life. A number of studies have shown that reducing the temperature (25 ° C lower), extended the tool life up to three times longer. At the same time the cutting fluids need to meet the demands of the multi-effect, i.e. cutting, lubrication, cleaning and emulsifying with sufficient corrosion resistance, microbial degradation (bacteria, molds, fungi) and low aggressiveness against the machine parts. Due to this fact, it is logical that if the particular cutting fluid meets all these requirements, it can not be a simple substance, but a synergistic blend of several components that provides the desired multifunctional effect. [1] As part of the machining process the cutting fluid evaporates, plotting as a liquid film on the surface of the workpiece, therefore it is necessary to keep it replenished. Depending on the amount of the cutting fluid loss or not even depletion of some of its components, there is a change of concentration, which may result in a deterioration of its characteristics which can have a negative impact on the stability of the machining process [3]. Prescribed concentration of cutting fluid can also be changed due to the impact of its complementation. Many studies have also demonstrated a significant influence of the cutting fluid for removing chips and improving their brittleness, which contributes to the achievement of the higher quality of the new surface. The aim of this paper is to describe the effect of the concentration of cutting fluid JCK HBs + H_2O on the appropriate chip formation in face milling and also achieving a favourable quality new surface when machining structural steel EN C45 (STN 12 050).

2. APPLICATION OF THE CUTTING FLUID IN MILLING

Milling machining process is the way in which the bearer of the main cutting motion of the rotary cutter is a tool-bearer and the feed is the workpiece [7]. For cooling and reducing the friction between the tool and the workpiece during milling a number of cutting fluids on the basis of oil, water and an emulsifier are often used. [4]. Since these emulsions are mixtures of variety of fluids with the prescribed ratio, the most commonly is prescribed % of oil components which are between 2% - 10%, the change of their ratio has a significant impact on the resulting properties. With the varying of the concentration of the emulsion applied to the incision site, the effects of cutting force on the cutting edge of the tool can be modified. The result of modification may result in the better machined surface quality, higher productivity [5], less forced downtime, caused by the reducing the need for exchange of the worn-out tool and so on. [8].

Friction node in place of a cut is a machined surface and a chip that is formed by the main cutting edge of the tool. (see Fig. 1). It is mainly the rubbing of the chip against the cutting edge tool that causes the excessive cutting tool load. Application of cutting fluid at the friction node:

1 – at the site of the chip formation
2 – emerging between the chipping and the face cutting edge tool
3 – between the machined surface and the back of the cutting edge

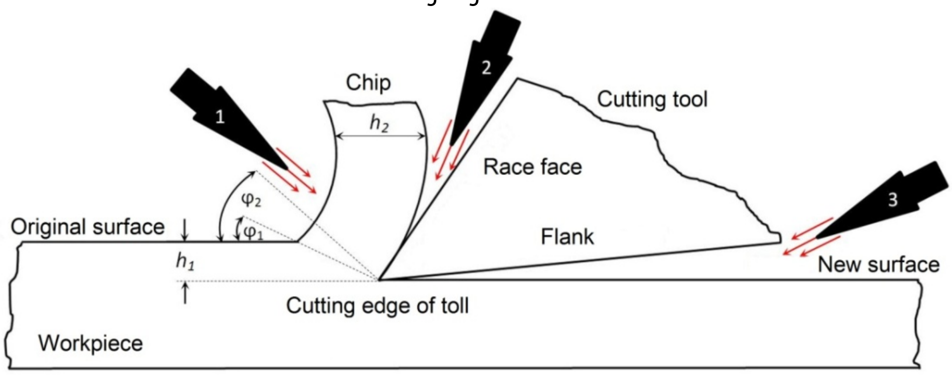

Figure 1. Possible options of the appropriate application of cutting fluid at the friction node (at the incision site) in milling

3. MATERIALS AND CONDITIONS FOR THE EXPERIMENT

The experiment was performed while machining structural steel EN C45 (STN 12 050). It is a fine carbon steel which is suitable for refining and casehardened with the strength of 590 ÷ 710 MPa and hardness in the soft annealed condition max. HB 200, the achievable hardness after quenching HRC 62, its chemical structure is shown below in table 1.

Table 1. Chemical composition of structural steel EN C45 (STN 12 050)

C	Si	Mn	Ni	P	S	Cr	Mo
0.43 ÷ 0,5	max 0.4	0.5 ÷ 0.8	max 0.4	max 0.045	max 0.045	max 0.4	max 0.1

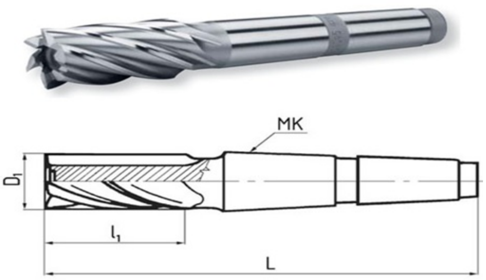

Figure 2. End mill with shank

As a tool the end mill with shank was used as shown in the following Figure 2:

Table 2. Basic parameters for end mill with shank

D_1 [mm]	L [mm]	l_1 [mm]	Flute amount	MK	Material	Tool Usage
40	188	63	6	4	HSS	- automatic and structural steel to 600MPa - structural cast steel up to 850MPa - tempered steels up to 900Mpa - cast iron to 240HB

The following table 3 lists a range of basic technological parameters, which were used in an experimental version of the samples.

Table 3. Range of basic technological parameters used in drawing samples

Cutting speed v_c[m.min^{-1}]	Feed v_f[mm.min^{-1}]	Feed per Tooth f_z[mm]	Feed per Spindle f_n[mm]	Depth of Cut a_p= a_e[mm]	Tool Spindles n [ot.min^{-1}]	Power P_{mot}[kW]
28.13	63.00	0.0468	0.281	20 ÷ 40	224	2.5 ÷ 4.5

Following figure 3 shows different methods of milling in which experimental samples were drawn.

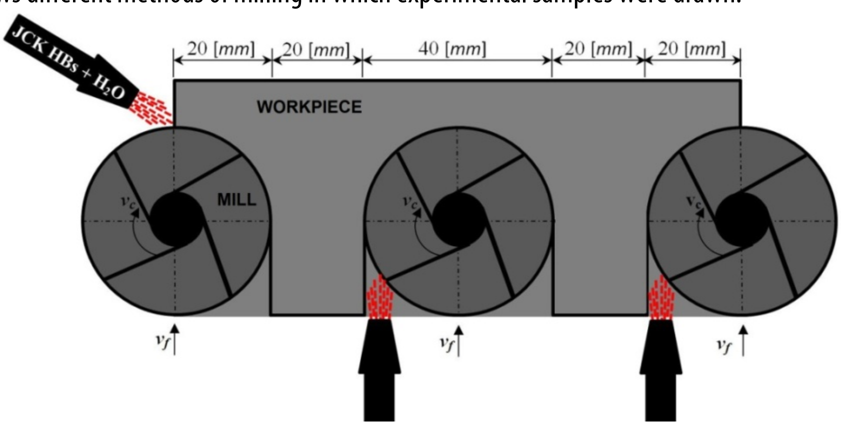

Figure 3. Methods used for milling at which the samples were drawn. v_c– cutting speed; v_f– feed, 1. parallel milling; 2. counter-rotating milling cutters with full engagement; 3. simultaneous milling cutters with full engagement; 4. dual-milling

As a cutting fluid emulsion was used JCK HBs water-based and oil, the essential characteristics are listed in the following table 4.

4. IMPACT OF EMULSION CONCENTRATION ON MORPHOLOGY AND CHIP FORMATION IN FACE MILLING

Possible modification of the action of cutting force on the cutting edge of the tool and chip formation and the resulting formation of the surface morphology of chips collected by changing the concentration of cutting fluid JCK HBs + H_2O, on the base emulsion in the range of 5% to 40%, in the different methods of milling structural steel EN C45 (STN 12 050) are shown in the following figure 4.

Picture 5 shows for comparison the nature of the chip surface by cooling the incision site with water and a stream of air in the different methods of milling with the same settings of process parameters that were used in the experimental version of the samples with the use of cutting fluid with different concentrations.

As can be seen and observed from Pictures 4 and 5, there are differences in the formation and the morphology of the surface of the chip, depending on the cooling method and the concentration of the cutting fluid JCK HBs + H_2O based on oil-water base, those differences significantly vary while constantly following the constant process parameters during the performance of all the experimental samples.

Based on the assumption that the nature and the quality of the machined surface, to some extent also depends on the shape of the surface of the chip can be concluded that with increasing concentration of the emulsion can achieve a higher quality of the machined surface.

Table 4. Basic characteristics of the emulsion oil JCK HBs

Physico-chemical properties		
Parameter	Value	Measure
Physical state at 20 [°C]	liquid	–
Colour	yellow-brown	–
Density at 20 [°C]	1 110	[$kg.m^{-3}$]
Fire point	>100 (without water)	[°C]
Kinematic viscosity at 20 [°C]	>8 (5% concentration)	[$mm^2.s^{-1}$]

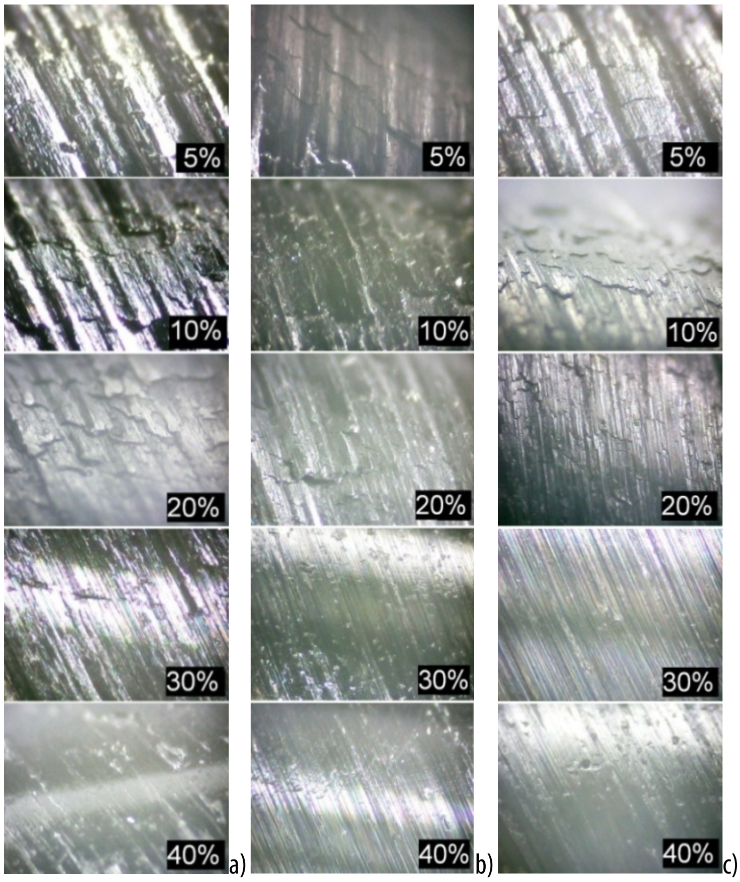

Figure 4. The morphology of the surface of chips, when machining steel C45 with different concentrations of cutting fluid JCK HBs + H_2O, at different ways of using the end mill (magnification 80x). a) full engagement; b) counter-rotating milling;

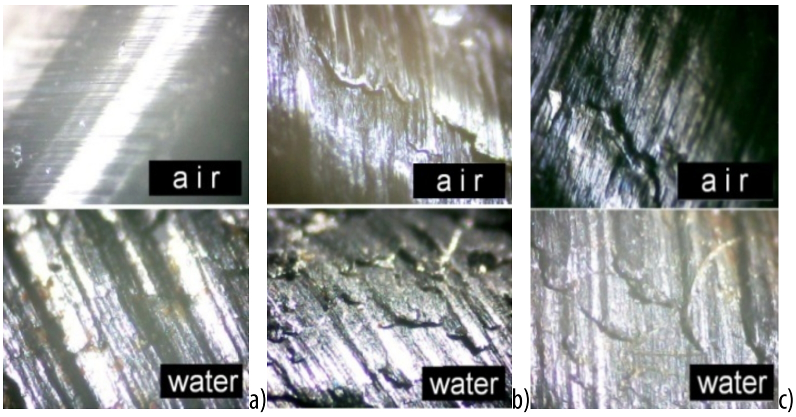

Figure 5. The morphology of the surface of chips when machining steel C45 with air cooling and water at different ways of using the end mill (magnification 80x)
a) full engagement; b) counter-rotating milling; c) parallel milling

5. CONCLUSION

The aim of this article, based on experimental observations showing the example of machining structural steel EN C45 (STN 12 050) with the use of the end mill, is to show the importance of compliance with prescribed concentrations of cutting fluid JCK HBs + H_2O- oil-water based, having a direct impact on the character formation and the chips surface morphology, which undoubtedly reflects the quality of machined surface. It is therefore necessary to ensure the stability of the cutting process when machining and it is necessary to regularly check the concentration of cutting fluid, and to maintain its value at the prescribed level.

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