Effect of Hydraulic Oil Entering the Cutting Fluid on the Tool Life and Roughness in Milling of Structural Steel

Alexey Popov, Mikhail Khramenkov
Department of Machining and Assembly, Faculty of Mechanical Engineering, Technical University of Liberec, Studentská 1402/2, 461 17 Liberec 1, Czech Republic. E-mail: alespopov@yandex.ru, khrmih@gmail.com

Thanks to their chemical and physical properties, the cutting fluids can significantly affect the process of machining - the use of cutting fluid reduces the roughness of the machined surface and increases the tool life. However, during the machining the oil from the hydraulic system of the machine often gets into the cutting fluid, which can alter the properties of the cutting fluid. In scientific literature there is no information on the effect of the hydraulic oil entering the cutting fluid on the tool life and roughness in machining of the structural steel. In this regard, at the laboratory of the Department of Machining and Assembly of the Technical University of Liberec, there has been conducted a study to ascertain the effects of hydraulic oil getting into different types of cutting fluids during the milling of structural steel.

Keywords: Machining, Milling, Cutting fluid, Wear

1 Introduction

The use of various types of tool cooling can increase the durability of the cutting tool, reduce the surface roughness and cutting forces and influence on the properties of the surface layer of machined components [1–9]. The use of cutting fluids in metal cutting is one of the most inexpensive and effective ways of cooling and lubrication [10, 11]. However, often, if not always, the oil from the hydraulic system of the machine gets into the cutting fluid, which can alter the properties of the cutting fluid.

A review of the literature revealed that the penetration of the oil from the hydraulic system of the machine in various types of cutting fluids (emulsion, synthetic cutting fluid, and semi-synthetic cutting fluid) during the milling of stainless steel does not cause deterioration of the cutting tool life and does not increase the roughness parameters of the machined surface [12]. In this regard, the practical interest lies in the determination of the effect of certain concentrations of hydraulic oil entering different types of cutting fluids, on tool life and surface roughness during the milling of structural steel, which used in industry more often than stainless steel.

The experiments performed at the laboratory of the Department of Machining and Assembly of the Technical University of Liberec guaranteed identical processing conditions and reliability of results.

2 Experimental procedures

In order to determine tool life when using different cutting fluids, the experiments were carried out by milling on the milling machine FNG 32 with manual control.

The cutter used for milling was a 63 mm - diameter cutter by the company Narex l.t.d. Milling of the structural steel Fe37B3FN (117 HB) was performed with the cutting inserts SNUN 120412 of hard alloy S26 (P15 – P30) at a cutting speed of V_c = 119 m/min, feed f_z = 0.1 mm/tooth, depth of cut a_p = 1 mm, width of cut a_e = 30 mm. The experiments were carried out with one insert fixed to the milling cutter.

Each cutting edge was worn on the back surface to 0.5 mm. To determine the average resistance value each experiment was repeated 5 times. Wear of the back surface was measured by using a Brinell Magnifier tool (magnification 24x, accuracy 0.05 mm).

We used three different types of cutting fluids: Blasocut emulsion based on mineral oil, the synthetic cutting fluid Vasco, and the semi-synthetic cutting fluid Zubora. For all machining experiments, 5% solution of water and an emulsion concentrate was prepared. The cutting fluid concentration was controlled by the refractometer Optech Brix RLC / ATC, characterized by concentration mea-sure-ment at a range of 0-18% and accuracy of 0.1%. The desired value for each fluid was calculated by the refractometer K using the following formula: K = 5/In, with 5 being the required concentration of 5%, and In being the refraction index whose value was provided by the cutting fluid manufacturer.

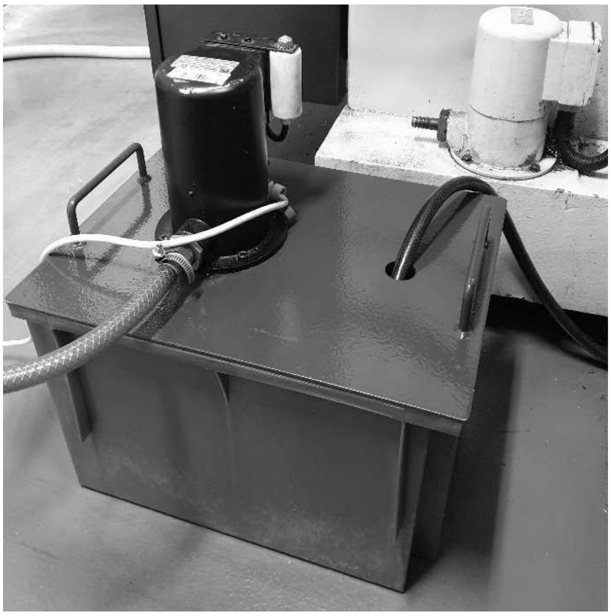

Fig. 1 *External cooling system of the milling machine FNG 32*

The hydraulic oil Paramo HM 46 was added to each cutting fluid. The mixing of 5% cutting fluids and hydraulic oil was performed in the external tank of the cooling system of the milling machine FNG 32 ***(Fig. 1).*** Different amounts of hydraulic oil were added to the same amount of cutting fluid, thus providing different concentrations of the hydraulic oil in the cutting fluid.

Experiments were conducted with four states of the cutting fluids, namely without hydraulic oil in the cutting fluid; with hydraulic oil concentration of 13 ml per 1 l of cutting fluid; with hydraulic oil concentration of 26 ml per 1 l of cutting fluid; and with hydraulic oil concentration of 39 ml per 1 l of cutting fluid. After standing, the hydraulic oil covered the surface of the cutting fluid.

Roughness measurements were performed by a profilometer MITUTOYO Surflest SV-2000 N2. Each measurement of roughness was repeated 10 times, and based on this the average force value was determined. Roughness parameters were measured in the direction perpendicular to the cutting direction.

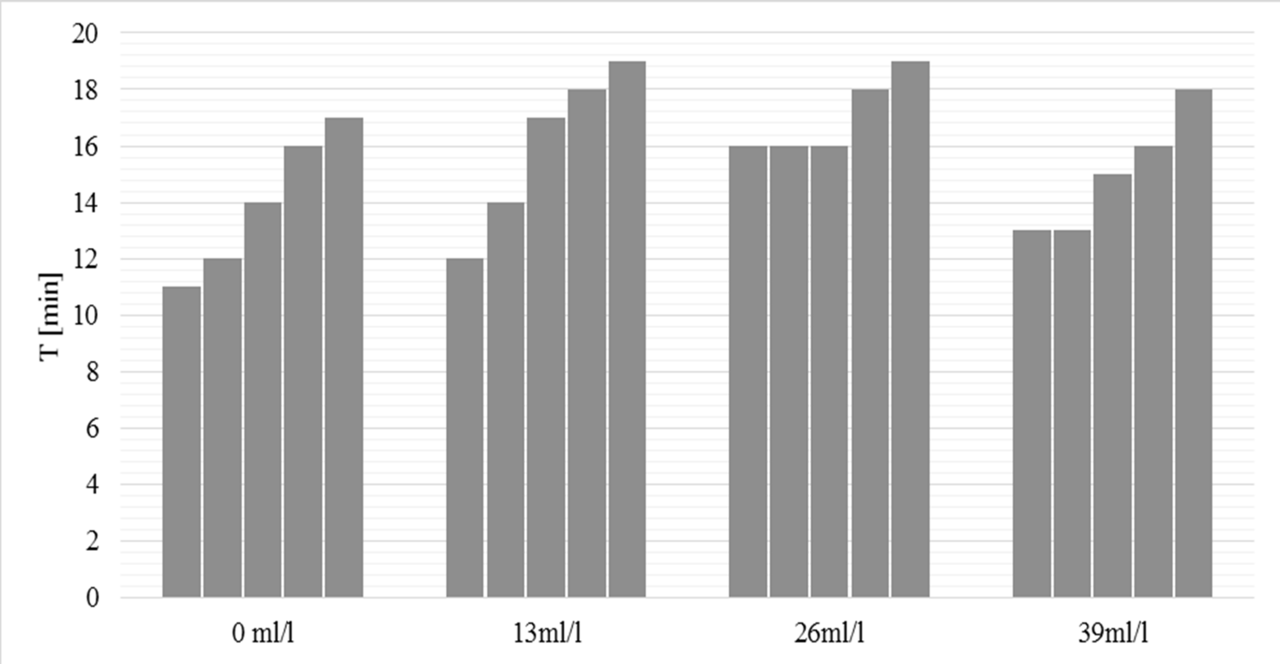

Fig. 2 *The effect of hydraulic oil content in the Blasocut emulsion on tool life T*

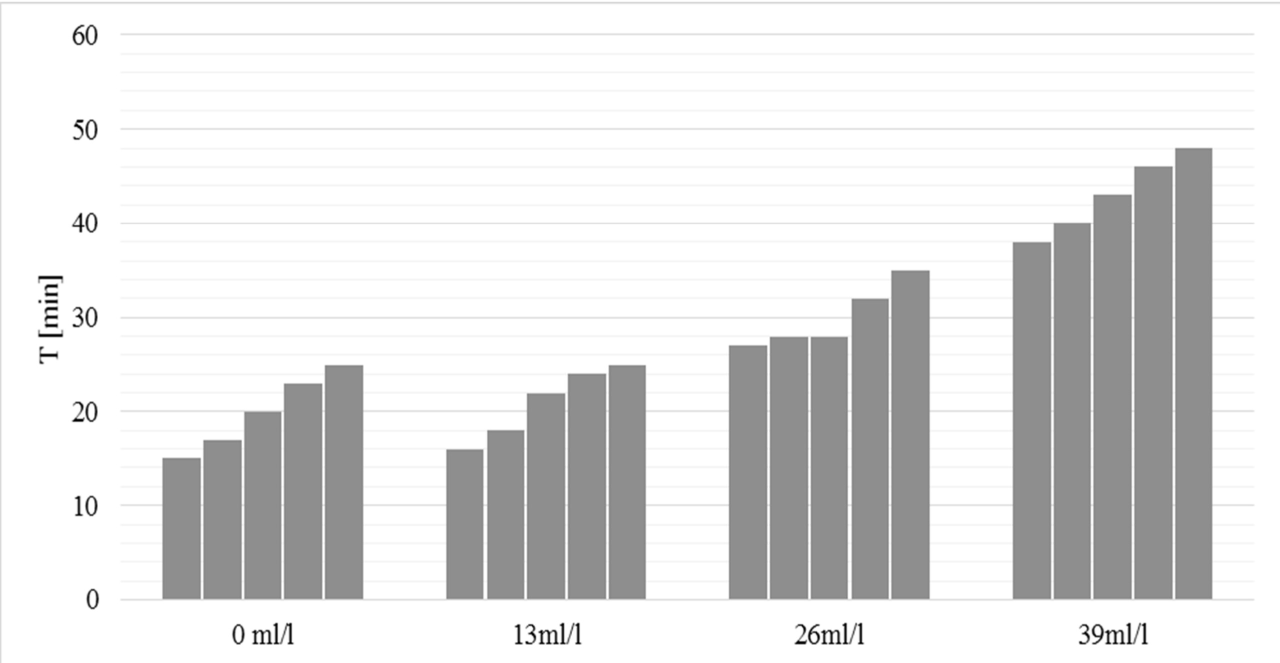

Fig. 3 *The effect of hydraulic oil content in the synthetic Vasco cutting fluid on tool life T*

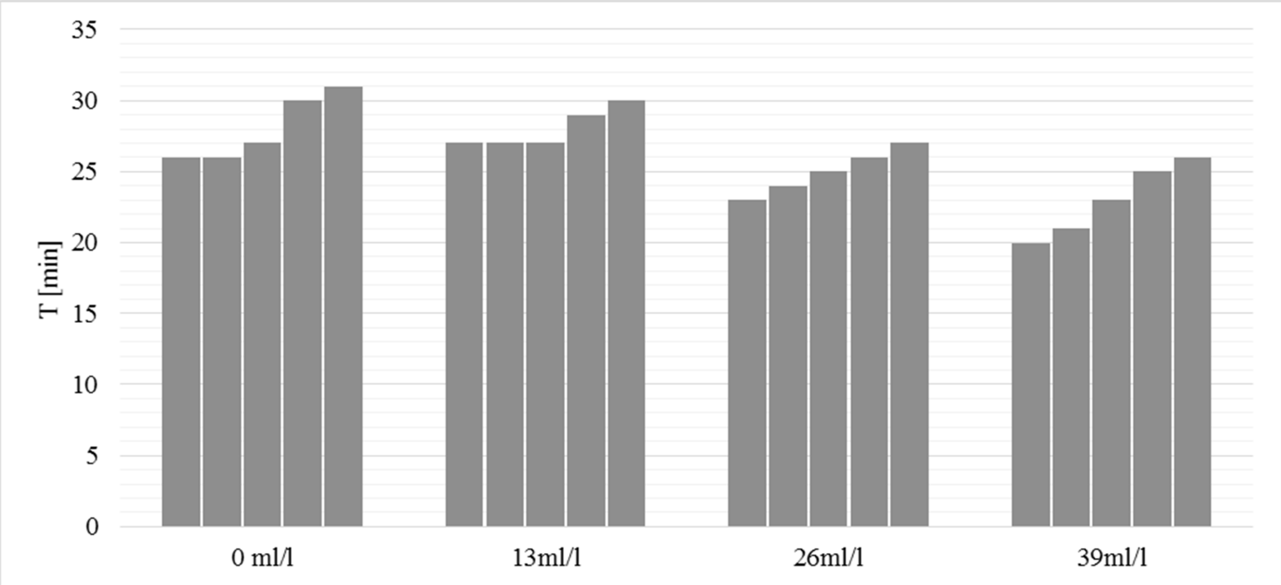

Fig. 4 *The effect of hydraulic oil content in the semi-synthetic Zubora cutting fluid on tool life T*

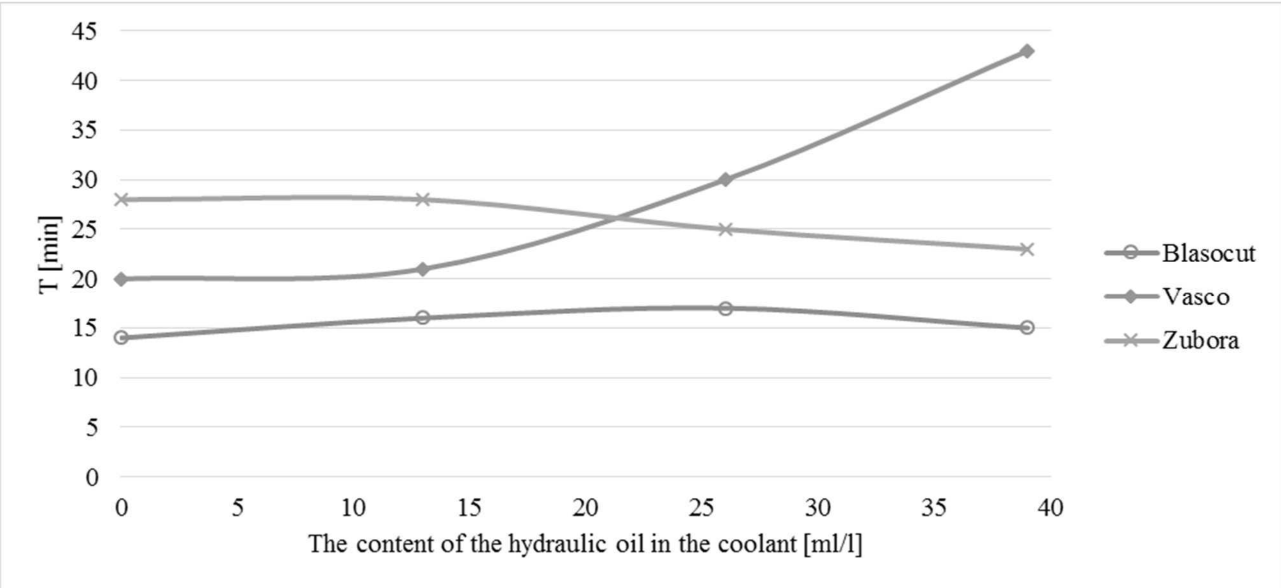

Fig. 5 *The effect of hydraulic oil content in different cutting fluids on tool life T*

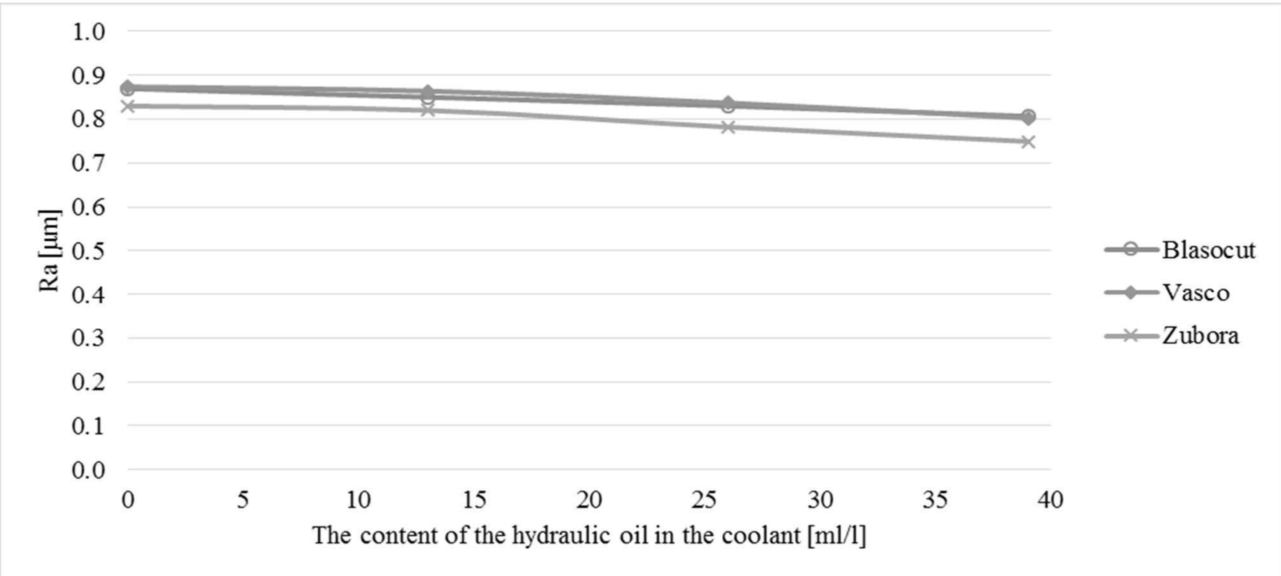

Fig. 6 *The effect of hydraulic oil content in different cutting fluids on parameter Ra*

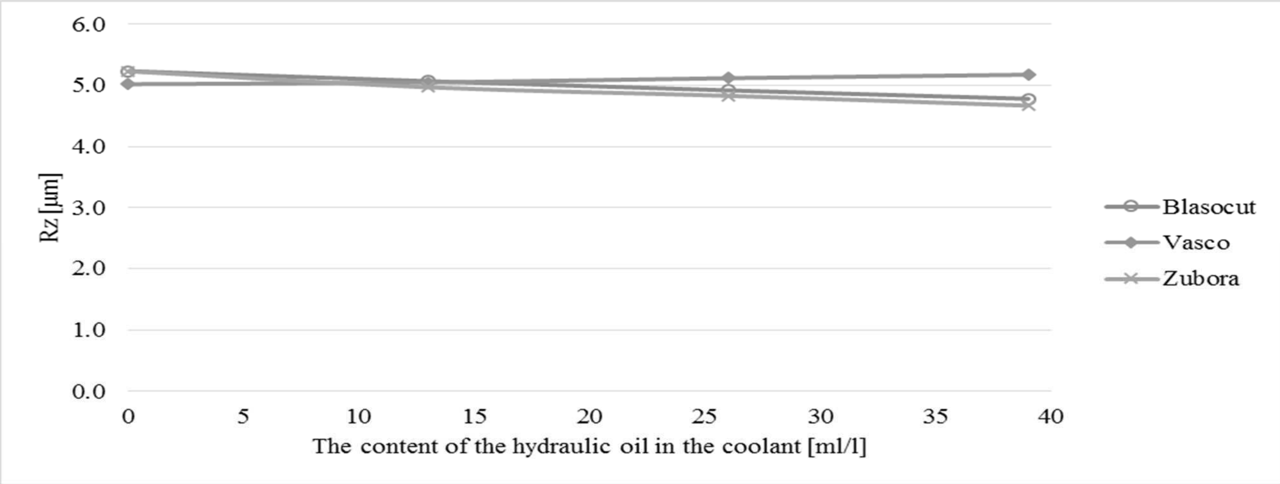

***Fig.** 7 The effect of hydraulic oil content in different cutting fluids on parameter Rz*

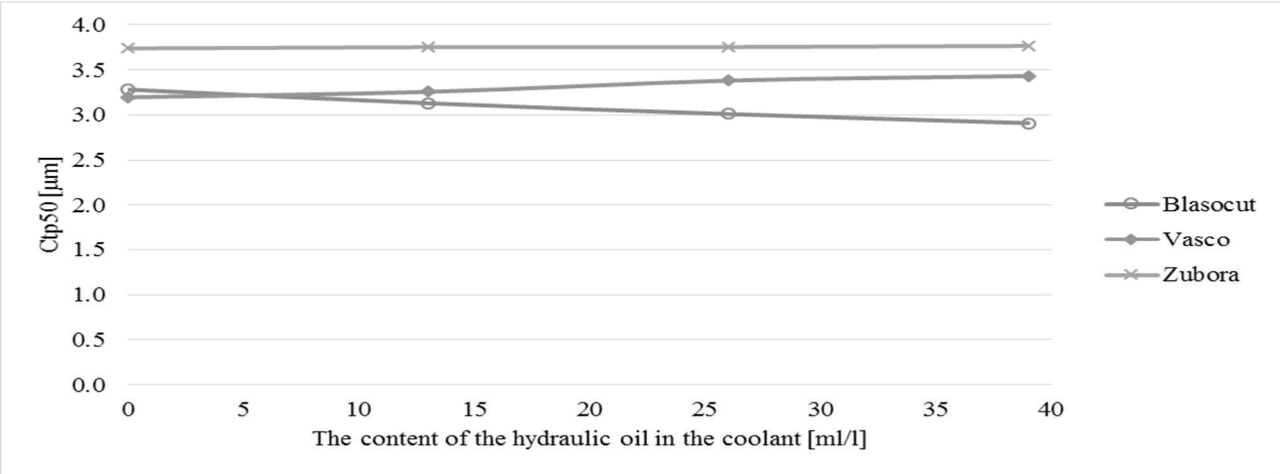

***Fig.** 8 The effect of hydraulic oil content in different cutting fluids on parameter ctp50*

3 Experimental results and analysis

The experiments have shown that the 13ml/l penetration of hydraulic oil does not influence on the tool life in all types of studying cutting fluids.

In case of using Blasocut emulsion, the increase in hydraulic oil concentration to 26 ml/l increased tool life by 21%. The 39 ml/l increase of hydraulic oil concentration resulted in a 7% tool life gain ***(Fig. 2).*** It means that the addition of the hidraulic oil in Blasocut emulsion does not give high effect on the tool life, possibly, because emulsion contents oil in it’s composition and additional oil does not cardinally change properties of the cutting fluid. It can be assumed that the Blasocut emulsion provides high lubricating properties and the growth of hydraulic oil's concentration does not increase these properties and the tool life.

The experiments have shown that the penetration of hydraulic oil in the synthetic cutting fluid Vasco with a concentration of 13ml/l resulted in a 5% tool life gain; the increase in hydraulic oil concentration to 26 ml/l resulted in a 50% tool life gain; and the increase of concentration to 39 ml/l increased the tool life by 115% ***(Fig. 3)***. It means that it is possible to increase the lubricating properties of the synthetic cutting fluid Vasco by increasing of the hydraulic oil's concentration, possibly, because synthetic cutting fluid does not content oil in it’s composition, so penetration of the hydraulic oil increases lubricating effect of the fluid and influence on the tool life.

The experiments have shown that the penetration of hydraulic oil in the semi-synthetic cutting fluid Zubora with 26 ml/l oil concentration resulted in 11% tool life decrease; the increase in hydraulic oil concentration to 39 ml/l resulted in a 18% tool life decrease ***(Fig. 4)***. It can be assumed that the semi-synthetic cutting fluid Zubora provides high lubricating properties and the growth of hydraulic oil's concentration does not increase these properties and the tool life. Opposite, the hydraulic oil addition decreasing cooling effect of the cutting fluid so the tool life slightly decreases.

The comparative analysis has shown that when the oil from the hydraulic system of the machine is not present in the cutting fluid, the greatest tool life is provided by the semi-synthetic coolant Zubora. The use of the synthetic cutting fluid Vasco leads to a reduction in tool life by 29%, and the use of the Blasocut emulsion reduces tool life by 50%. For the 39 ml/l concentration of hydraulic oil in the cutting fluid, the use of the synthetic cutting fluid Vasco shows the best result, using semi-synthetic cutting fluid Zubora gave 47% tool life decrease, while when using the Blasocut emulsion the tool life is reduced by 65% ***(Fig. 5)***. Such a result can be explained by the fact that synthetic cutting fluid Vasco does not content oil in it's composition, so 39 ml/l oil concentration in it cardinally changes lubricating properties of this coolant.

It has been established that when the oil from the hydraulic system of the machine is not present in the cutting fluid, the lowest roughness parameter R_a is provided using semi-synthetic cutting fluid Zubora. The use of the synthetic cutting fluid Vasco and Blasocut emulsion increases the roughness parameter R_a by 5%. For the 39 ml/l concentration of hydraulic oil in the cutting fluid, the use of the semi-synthetic Zubora cutting fluid produces the lowest roughness parameter R_a, while the use of the synthetic cutting fluid Vasco and the Blasocut emulsion increases the roughness parameter R_a by 7% ***(Fig. 6)***.

The studies have shown that when the oil from the hydraulic system of the machine is not present in the cutting fluid, the lowest roughness parameter R_z is provided using the synthetic cutting fluid Vasco; the use of the Blasocut emulsion and the semi-synthetic cutting fluid Zubora increases the roughness parameter R_z by 4%. For the 39 ml/l concentration of hydraulic oil in the cutting fluid, the lowest roughness parameter R_z is provided using the Zubora coolant. The use of the Blasocut emulsion increases the roughness parameter R_z by 3% and the use of the synthetic Vasco cutting fluid increases the roughness parameter R_z by 11% ***(Fig. 7)***.

The comparative analysis has shown that when the oil from the hydraulic system of the machine is not present in the cutting fluid, the lowest roughness parameter c_{tp50} is provided using the synthetic cutting fluid Vasco and the Blasocut emulsion. The use of the semi-synthetic cutting fluid Zubora increases the roughness parameter c_{tp50} by 17%. For the 39 ml/l concentration of hydraulic oil in the cutting fluid, the lowest roughness parameter c_{tp50} is provided using the Blasocut emulsion. The use of the synthetic cutting fluid Vasco increases the roughness parameter c_{tp50} by 18% and the use of the semi-synthetic cutting fluid Zubora increases the roughness parameter c_{tp50} by 30% ***(Fig. 8)***.

4 Conclusion

The studies have shown that the penetration of the oil from the hydraulic system of the machine in the semi-synthetic cutting fluid and emulsion during the milling of structural steel does not cause deterioration of the cutting tool life, and does not increase the roughness parameters of the machined surface.

It has been established that the penetration of the oil from the hydraulic system of the machine in the synthetic cutting fluid during the milling of structural steel increases the cutting tool life, and does not increase the roughness parameters of the machined surface.

Acknowledgments

This article is related to the investigation on the Specific University Research Projects which are supported by the Ministry of Education (MSMT) of the Czech Republic.

References

[1] JERSÁK, J., VRKOSLAVOVÁ, L. (2013). The influence of process fluids on the properties of the surface layer of machined components, *Manufacturing Technology*, 13(4), pp. 466-473

[2] POPOV, A., DUGIN, A. (2014). Study of reasons of increased active force using coolant with uncut chip thickness, *International Journal of Advanced Manufacturing Technology*, 70(9-12), pp. 1555-1562

[3] POPOV A, DUGIN A. (2013). Influence of lubricant and coolant fluid on the cutting force in small-increment planning, *Russian Engineering Research*, 33(2), pp. 84-85

[4] JERSÁK, J., KAPLAN, F. (2015). Comparison of the influence of process fluids on tool life in face milling, *Manufacturing Technology*, 15(6), pp. 977-984

[5] JERSAK, J., ZIZKA, J. (2015). Essential features of process fluids applied in machining, *Manufacturing Technology*, 15(6), pp. 985-991

[6] BAKALOVA, T., SVOBODOVA, L., BORUVKOVA, K., LOUDA, P., VOLESKY, L. (2016). The influence of nanoadditives on the tribological properties of process fluids, *Journal of Physics: Conference Series* 709(1), article number 012001

[7] JERSÁK, J., SIMON, S. (2017). Influence of cooling lubricants on the surface roughness and energy efficiency of the cutting machine tools, *International Journal of Applied Mechanics and Engineering*, 22(3), pp. 779-787

[8] POPOV, A., KRASNIKOVA, I. (2018). Reducing labor intensity in the development of new universal cutting fluids for machining, *Manufacturing Technology*, 18(1), pp. 99-105

[9] ŠRAMHAUSER, K., NÁPRSTKOVÁ, N., KRAUS, P., MAREK, M. (2018). Comparative study of flank wear, tool life and type of chips for two similar turning inserts from different producers, *MATEC Web of Conferences*, 244, article number 02008

[10] DUGIN, A., JERSAK, J., POPOV, A. (2014). Method for determining of the anti-adhesion ability of cutting fluids, *Manufacturing Technology*, 14(2), pp. 145-149

[11] DUGIN, A., VOTOCEK, J., POPOV, A. (2014). Method for determining the tribological properties of the cutting fluid, *Manufacturing Technology*, 14(2), pp. 149-153

[12] POPOV, A., SCHINDELARZ, R. (2017). Effect of hydraulic oil entering the cutting fluid on the tool life and roughness in milling of stainless steel, *Manufacturing Technology*, 17(3), pp. 364-369

10.21062/ujep/316.2019/a/1213-2489/MT/19/3/482