

EFFECT OF NATURAL FILLERS IN THE FORM OF NANOPARTICLES ON THE TRIBOLOGICAL PROPERTIES OF PROCESS FLUIDS

Totka BAKALOVA, Lukáš VOLESKÝ, Petra ŠKODOVÁ, Petr LOUDA

Institute for Nanomaterials, Advanced Technology and Innovation, Technical University of Liberec, Studentská 2, 461 17 Liberec, Czech Republic, totka.bakalova@tul.cz

ABSTRACT

Technological attributes of the process fluids (PF), especially their tribological and anti-adhesion behavior during the machining are very important. The aim of the tribology is to ensure, that the relative motion of two surfaces is happening with the least energy and material loss. During the machining leads to contamination of process fluids due to the technological process. These contaminations can be strongly expressed not only by inappropriate actions of the fluid during the technological process, but also by increased in economic costs. The quality of the process fluid is also influenced by a bacterial infection. Using natural fillers in a form of nanoparticles is one of the ways how to inhibit bacteria and improve a biological and technological stability of the fluids. The resistance of process fluids against bacterial infection defines consequent lifetime of the fluid.

Keywords:

Tribology, process fluids (PF), nanoparticles

1. INTRODUCTION

The development of high-strength materials, modernization of methods of measurement in the field of material sciences and long experience with the operation of advanced technological systems show that the surface layer significantly affect their durability and reliability. With the increasing intensity of machining processes increase the cutting speed and the growth fields temperature in the surface layers of machine parts. Consequently, in many cases the mechanical and physical surface characteristics are considerably different from core. The surface condition gives basic information about its quality and also it allows to understand the various processes occurring in the surface layer. Most analyzed parameters are the surface roughness and hardness. Apart from these values are increasingly analyzed the tribological properties of the newly created functional surfaces as well as corrosion and fatigue resistance or susceptibility to crack spreading. [1]

An important factor affecting the lifetime of process fluids (further PF) is their particulate contamination during the machining process. Apart from the organic impurities in the PF releases a large amount of solid particles generated during cutting. The amount of these particles in the liquid depends primarily on the anti-adhesiv and tribological properties of specific PF. [2]

1.1 Machining technology

Machining technology is an industry that is still rapidly evolving, both in the field of machine tools, in the field of cutting tools and not least in the field of process media. [2 - 4] Today is in production consumed large quantities of process fluids. In the case of metal cutting the PF affect mainly the work of friction on the contact surfaces between the tool and the workpiece; the mechanics of chip formation; topography and hardening of the machined surface. Fine process liquid must have an anti-corrosion properties, can not create sticky deposits and may not cause changes of the surface of the metal. [5 – 8]

1.2 The mechanism of friction and wear

The friction is an important factor in the mutual behavior of two moving bodies. Depending on the speed of movement and on its type we can recognize different types of friction. The doctrine about the interaction of surfaces in mutual (relative) movement is called tribology. Friction shows and effects depend on many factors such as the contact area or the substance which is between the bearing surfaces and surrounding areas. Explanation of the tribological process is associated with the inception of frictional forces and wear of particles. [6]

Frictional force from the perspective of micromodel can be caused by diffusion of molecules and atoms of mutually touching surfaces. Between the abutting overhangs of inequalities are formed micro-welds and adhesion occurs. Another option is capturing the micro-inequalities of surfaces, which can be caused by particles that reached between the surfaces. Abrasion occurs, which is marked as a mechanical action. If the friction is viewed from the macromodel point of view it is understood as a resistance against the movement arising between two bodies in contact of their surfaces in tangent direction to the surfaces which is referred to as the outer friction. [6]

The result of the interaction of the friction elements is wear; a process of removing material from the surfaces of both parts of the friction pair. Basic causes of wear are elastic and plastic deformation of the surface roughness peaks and their reinforcement; forming of oxidation layer; pushing the particle of surface layer of one material to another and the adhesive connection between the protrusions of the friction elements. In practice, the wear is the result of several factors one of which is dominant and that mainly determines the size of wear. The most common mechanism is abrasive wear, which accounts for 80-90 % of all tribological wear. The literature indicates several types of material damages according to the degree of deformation around the contact inequalities: elastic deformation; plastic deformation; grooving and the adhesive bond. Wear is mostly caused by mechanical influences, but in fact it can occur in combination with other factors; eg. chemical or electrochemical. [5, 9, 10, 11]

1.3 Nanoparticels and their use

At present, nanotechnology is one of the most discussed technologies. Metal ions, are used as a method in the fight against bacteria for a long time.

Using natural fillers in the form of nanoparticles has a high efficiency due to their high chemical and biological activity. The use of nanoparticles is a possible way of elimination of bacteria and improve the biological; chemical and technological stability of liquids. Suitable alternatives for the development of antimicrobial agents are synthesized nanoparticles of metals which are bactericidal (mainly nanoparticles based on silver). Nanoparticle with size less than 100 nm have a large surface area and it can interact more easily with biological materials. [12, 13]

2. MATERIALS AND METHODS

2.1 Evaluation of tribological tests

Tribology evaluates attributes that influence interaction of surfaces; environment and the body during their relative motion. It includes processes of influence on the line between solid; fluid and gaseous state of units. The main goal of tribology is to ensure the relative motion of two surfaces happens with the least energy and material loss. Tribological attributes describe most of all the coefficient of friction and wear. [5, 6] During the research of friction mechanism and effects we look at the system comprised of two units and their contact areas and a substance, which is between contact areas and close environment, as a tribological system.

The basis of tribological measurements is testing method "ball-on-disc". The measurement involves the injection of fixed attachments of the test piece ("ball") in the form of balls of the chosen material defined force to drive (test sample). An essential part is the friction sensor. The coefficient of friction between the unit and

the disc is determined during the test measurement. The coefficient of friction was determined using tribometer CETR UMI Multi-Specimen Test System (figure 1) and groove of the tribological test was evaluated by mechanical profilometer Dektak – XT (figure 2) from the BRUKER company.



Fig. 1 CETR UMI Multi-Specimen Test System

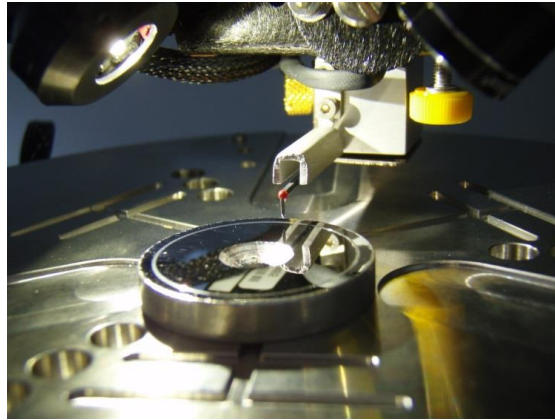


Fig. 2 Mechanical profilometer Dektak – XT

2.2 The addition of nanoparticles to the solution of process fluids

The aim of the modification of industrially supplied PF is increase of the biological stability of PF even after long-term use. The experiment was implemented at the Institute for Nanomaterials, Advanced Technology and Innovation, Technical University of Liberec (TUL).

Two standard supplied process fluids labeled as PF 1 and PF 2 were used in the experiment. Both process fluids have been modified by the addition of silver nitrate (AgNO_3) and ascorbic acid ($\text{C}_6\text{H}_8\text{O}_6$). The ascorbic acid has been chosen for the purpose of improving the antimicrobial and antioxidant activity and it is also able to reduce the metallic silver nanoparticles from the silver nitrate solution. Two variants of process fluids were prepared: only with the addition of silver or addition of silver and the vitamin C. Reduction of silver nanoparticles from silver nitrate was carried out by using UV radiation. UV irradiation was performed in a closed chamber using a high performance halogen metal vapour lamp with combination of metal halides generates strong radiation in the UVB range (280 - 315 nm) and especially in the UVA range (315 - 380 nm).

Reduction of silver nanoparticles resulted in a change in color of tested process fluids. In figures 3 and 4 is shown successively a) a 5% solution of pure PF; b) 5% solution PF with 0.3 g/l of AgNO_3 and c) 5 % solution of PF with the addition of 0.3 g/l AgNO_3 + 0.1 g/l $\text{C}_6\text{H}_8\text{O}_6$.

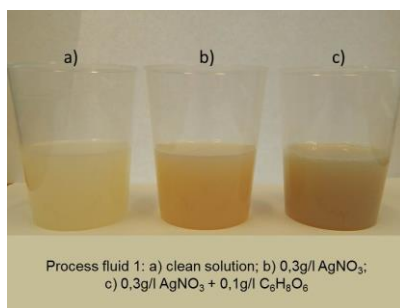


Fig. 3 Solutions of process fluid PF1

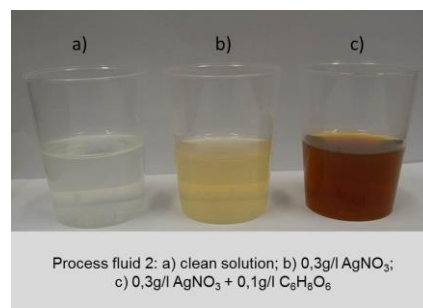


Fig. 4 Solutions of process fluid PF2

From the above figures it is evident that the reduction of the silver nanoparticles is more efficient in the case of combination of UV reduction + vitamin C. Darkening of the liquids means smaller size of final nanoparticles.

3. RESULTS

3.1 Tribological tests

Tribological testing (EN1071-13:2010) was conducted by using a ball made from Si_3N_4 with a diameter of 6.35 mm, with a constant load of 10 N at room temperature. The material of used disc was steel 16MnCr5 - EN 10084-94, EN 84-70 with a polished surface with roughness of $R_a = 0.01\mu\text{m}$. The radius of the circle over which the "Ball" body was moving was 11 mm and the friction coefficient measurement was carried out using a 5% solution of process fluid volume 100 ml.

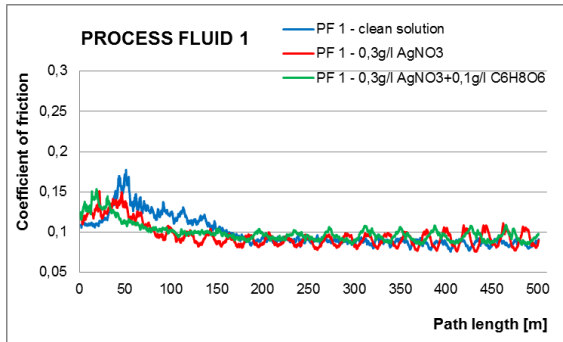


Fig. 5 Coefficient of friction PF 1

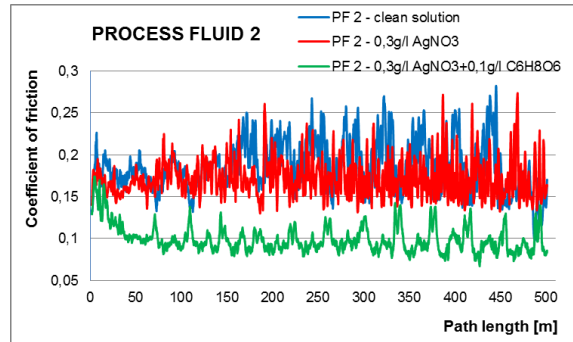


Fig. 6 Coefficient of friction PF 2

3.2 The groove of the tribological test

The part of tribology is to evaluate the groove profile at the end of the experiment. Mechanical profilometer Dektak-XT (figure 2) allows 3D imaging of groove of removed material during the process of friction. Results are shown in figure 7 - PF 1 and figure 8 – PF 2.

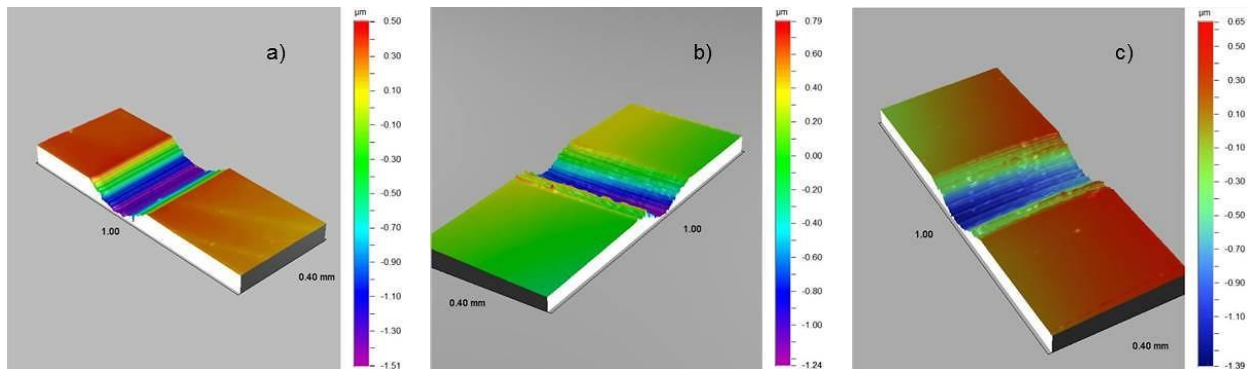


Fig. 7 3D Profile of PF 1 after tribology: a) clean solution; b) 0,3g/l AgNO_3 ; c) 0,3g/l AgNO_3 +0,1g/l $\text{C}_6\text{H}_8\text{O}_6$

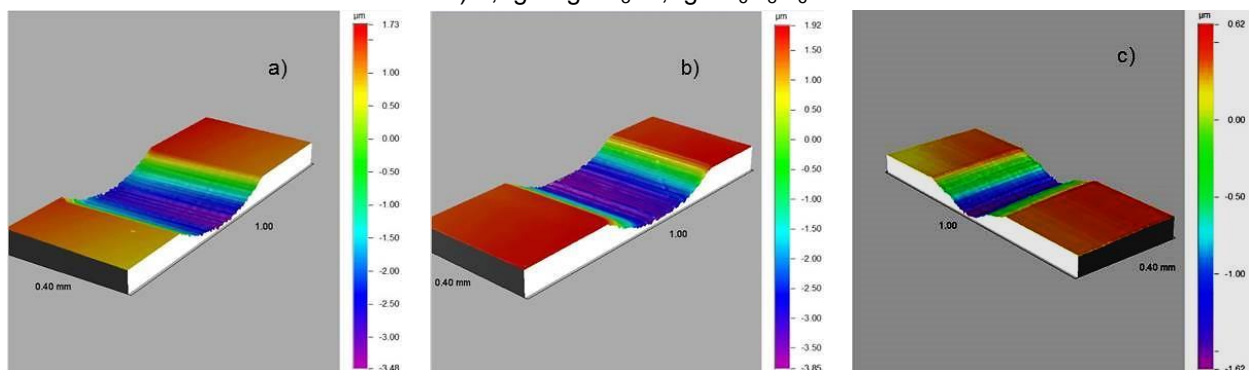


Fig. 8 3D Profile of PF 2 after tribology: a) clean solution; b) 0,3g/l AgNO_3 ; c) 0,3g/l AgNO_3 +0,1g/l $\text{C}_6\text{H}_8\text{O}_6$

4. CONCLUSION

The course of the experiment describes the process mechanism of the interaction of friction elements and wear. Experiment simulate the processes of splinter machining and allows the prediction of the behavior of process fluids in the practical deployment. Using the process fluids in the machining stage eliminates the increase of the friction coefficient (figures 5 and 6) at the beginning of the process and leads to reduction of wear of the cutting tools. Tribological tests (figures 5 and 6) shows that the addition of silver nitrate and ascorbic acid to 5% of aqueous process fluid has a positive effect on the decrease in the coefficient of friction during the tribological process. In case of PF 1 adding of nano-additives leads to a faster stabilization of tribological process under the certain experimental conditions, this is an important factor during machining.

For the PF 2 values of the coefficient of friction using a 5 % solution with the addition of 0.3 g/l AgNO₃ are unchanged. Adding of 0.3g/l AgNO₃ + 0.1 g/l C₆H₈O₆ led to a reduction in the coefficient of friction and achieve an average value of 0.11. Apart from the positive effect on the coefficient of friction for PF 2 the addition of additives in the form of nanoparticles led to a significant reduction in the volume of removed material from the substrate (figure 8 c).

The manufacturing process with process fluids has to be in accordance with European Union requirements that are specifically focused on environmental and health standards. Adding of natural nano-additives is one of the possible ways how to improve the PF properties and compliance with EU requirements.

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References

- [1] HAUK, V. et al.: Structural and Residual Stress Analysis by Nondestructive Methods, Elsevier Science B. V., 1997.
- [2] HOLMBERG, K, A MATTHEWS: Coatings tribology: properties, mechanisms, techniques and applications in surface engineering. 2nd ed. Boston: Elsevier Science, c2009, xv, 560 p., [3] p. of plates. Tribology and interface engineering series, 56. ISBN 978-044-4527-509.
- [3] HAUK, V a H. BEHNKEN: Structural and residual stress analysis by nondestructive methods: evaluation, application, assessment. New York: Elsevier, 1997, xiv, 640 p. Materials science and technology (Boca Raton, Fla.). ISBN 04-448-2476-6.
- [4] HUMÁR, A.: Materiály pro řezné nástroje. Praha: MM publishing, 2008, 235 s. ISBN 978-80-254-2250-2.
- [5] BURAKOWSKI, T., WIERZCHOŃ T.: Surface engineering of metals: principles, equipment, technologies. Boca Raton, Fla.:CRC Press, c1999, 592 p. Materials science and technology (Boca Raton, Fla.). ISBN 08-493-8225-4.
- [6] KRAUS, V., A MATTHEWS: Povrchy a jejich úpravy: Properties, mechanisms, techniques and applications in surface engineering. 1. vyd. Plzeň: Západočeská univerzita, 2000, 216 s. Tribology and interface engineering series, 56. ISBN 80-708-2668-1.
- [7] MITURA, K., NIEDZIELSKI, P., BARTOSZ, G., MOLL, J., WALKOWIAK, B., PAWŁOWSKA, Z., LOUDA, P., KIEĆ-ŚWIERCZYŃSKA, M., MITURA, S.: Interactions between carbon coatings and tissue, Surface & Coatings Technology 201 (2006) 2117–2123.
- [8] HOLLSTEIN F, KITTA D, LOUDA P, PACAL F, MEINHARDT J.: Investigation of low-reflective ZrCN-PVD-arc coatings for application on medical tools for minimally invasive Sumery, SURFACE & COATINGS TECHNOLOGY Volume: 142 Pages: 1063-1068, 2001.
- [9] KRAUS, V.: Povrchy a jejich úpravy, ZČU Plzeň, 2000.
- [10] HOUDKOVÁ, Š.: Hodnocení mechanických vlastností žárových nástřiků, [Disertační práce], ZČU Plzeň, 2004.

- [11] TICHOTOVÁ, P.: Hodnocení tenkých otěruvzdorných vrstev deponovaných metodou CVD, [Diplomová práce], ZČU Plzeň, 2004.
- [12] NOSONOVSKIĚ, M., P ROHATGI.: Biomimetics in materials science: self-healing, self-lubricating, and self-cleaning materials. New York, NY: Springer, c2012, xxvi, 415 p. Springer series in materials science, 152. ISBN 14-614-0925-X.
- [13] ČIHALOVÁ, K., CHUDOBOVÁ, D., KOPEL, P., ADAM, V., KIZEK, R.: Nanočástice kovů jako moderní nástroje pro potlačení růstu bakterií, Inovační podnikání & transfer technologií, p. 30 – 31, 1/2014.