The tribological behaviour of process fluids using different friction pairs

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Tribology includes the processes of interaction at the interface between solid, fluid and gaseous bodies. The task of tribology is to ensure that relative movement of the two surfaces was carried out with the minimum loss of energy and materials. These factors define the tribological properties of the newly created functional surface with the use of lubricants. Tribological properties mainly describes the coefficient of friction and wear, which depends on the type of friction and mechanism of wear.
During the examination of the effects and impacts of friction we look at the system consisting of two bodies, their contact surfaces and a material that is between them and close surroundings, such as the tribological system. Friction has a significant influence on the technological properties of process fluids and can lead to a reduction of lifetime and it can also change the functional properties. Lifetime of lubricating and cooling process fluids is one of the fundamental aspects that determine the quality of the fluid and its also affects the process and economic expensiveness.

Keywords: tribology, friction pair, process fluids, coefficient of friction, wear

1. INTRODUCTION

The machining technology is still rapidly evolving and an important direction of development is in the field of process media. [1, 2, 3] An important part of the production process are water miscible process fluids, which today are consumed in large amount in the production. During the machining the process fluids have a influence on the friction work of the contact surfaces between the tool and the workpiece, the mechanics of chip formation, topography and hardening of the machined surface. Furthermore, the process liquid must have a good anti-corrosion properties, should not create a sticky deposits and may not cause changes on the surface of the metal. [4, 5]

1.1 Effect of the machining technology on the quality of the surface layer

The cutting conditions during the machining (eg. cutting speed, type of tool material, finishing operations or type of applied lubricant) have a significant influence on the properties of the newly created surface layer.

Besides the parameters of the machining are important: the chemical composition of the tool and workpiece, tool geometry, the method of heat removal or lubrications. [6]

Each subsequent technological operations causes the redistribution of residual stresses on the machined surface. From literature sources it is known that on the quality of the surface layer has the greatest influence the last technological operation. But it is always necessary to consider the fact that inappropriately selected sequence of operations may remain in the surface layer maintained interference from previous machining operations. [7]

Use of a lubricant during a machining process reduces cutting forces (lubricating effect) and transfers heat from the surface (cooling effect). Directly therefore has concluded that lubrication causes a reduction in the size of the residual stress, and reduces the depth of the affected area. [8] The resulting lifetime of specific parts mainly depends on the local properties of the material in the most stressed location and not on the average performance of the entire cross-section.

2.1 The mechanism of friction pair

The tribological behavior evaluates not only the surfaces that are in contact during the tribological experiment. Tribology evaluate the tribological system as a whole - both surfaces and their properties, testing conditions (load, relative humidity, temperature, etc.) and the presence of lubricant. Friction is characterized by two basic factors: the friction coefficient defined by the ratio of friction (tangential) force to the load at the point of contact and wear, indicating the volume of the removed matreial from the surfaces during the experiment.

Wear is the process of destruction and removal of material from the surfaces of both parts of the friction pair due to the mutual motion of friction elements. There are various causes of the wear of the surface of friction pairs, basis are elastic and plastic deformation of the roughness peaks and their hardening, the formation of the adhesive bond between the protrusions of the friction elements, the injection of particles into the surfaces of both materials. Depending on the degree of deformation in the area of contact inequalities, there are different types of fracture, for example: grooving, the formation of adhesive bonding, elastic and plastic deformation. The most frequent cause of occurrence of wear are the mechanical effects, always in combination with other - the chemical and electrochemical [9, 10, 11].

2. MATERIALS AND METHODS

2.1 Evaluation of tribological tests and mechanical profilometer

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. [12]

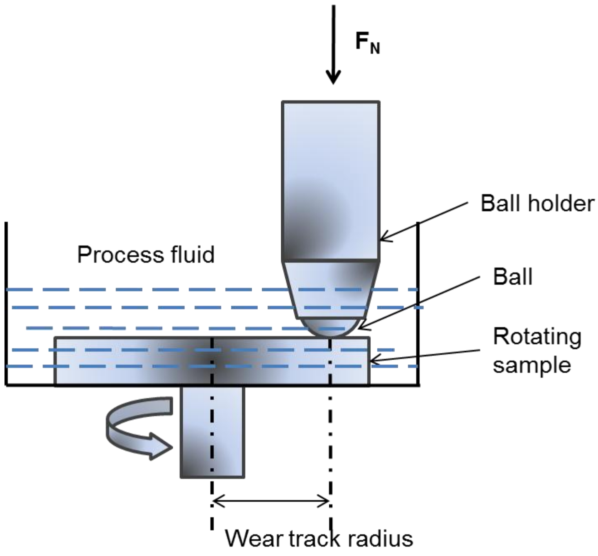

Fig. 1 Schematic representation of the contact with the sample

The coefficient of friction was determined using tribometer CETR UMI Multi-Specimen Test System (Figure 2) and groove of the tribological test was evaluated by mechanical profilometer Dektak – XT (Figure 3) from the BRUKER Company.

Fig. 2 CETR UMI Multi-Specimen Test System

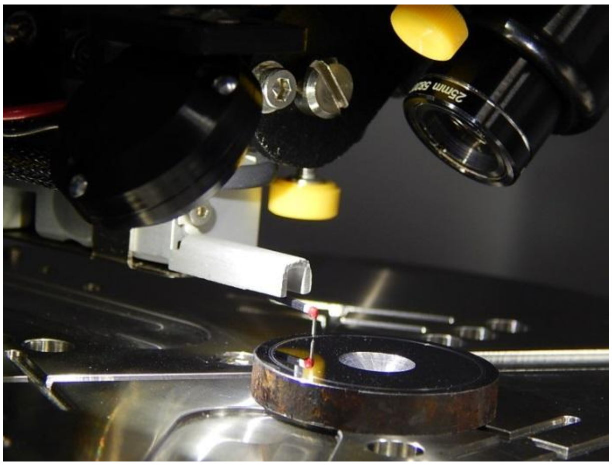

Fig. 3 The Mechanical profilometer Dektak – XT

Tribological testing (EN1071-13:2010) was conducted by using a ball made from Si_3N_4 with a diameter of 6.350 mm, with a constant load of 10 N at room temperature and humidity 40 ± 2 %. The materials disk was made of steel EN 10084-94 and ISO 683/13-86 and of aluminum EN AW 2030 with a polished surface with roughness of Ra 0.01µm. The radius of the circle along which the moving unit was 13 mm and measuring the coefficient of friction was carried out by using a 5% solution of process fluids with a volume of 100 ml.

The mechanical profilometer Dektak ™ XT (Figure 3) comes into the direct contact with the surface of the sample tip. Load must be selected according to the type of the sample, to prevent the mechanical damage (scratching) of samples, if the sample is soft and the force is disproportionately large. During the measurement the sample is placed on a substrate (Figure 3) and it is in direct contact with the tip. The inequalities on the surface of the sample are registered by tip that performs linear movement, samples moves relatively to the stationary tip. Mechanical profilometer scans the shape of the surface in the contact mode by contact with a diamond tip with the size of a few micrometers, thereby it is possible to study the surface morphology of the horizontal plane with size from hundred micrometers to tens of millimeters.

2.2 Process fluids

The experiment was focused on monitoring the changes in contact of ceramic ball bearing Si_3N_4 with a specific pad using a specific process fluid (PF). Pads have been produced from a material EN 10084-94, ISO 683/13-86 and EN AW 2030 and during the tribological experiment were used three different kinds of PF:

- Process fluid marked as PF 1 based on vegetable oil;
- Process fluid marked as PF 2 based on mineral oil;
- Process fluid marked as PF 3 - synthetic PF.

Observation of the coefficient of friction and amount of wear of investigated friction pairs under the same conditions tribological experiment has showed the differences in behavior of different kinds of PF using different friction pair.

3. RESULTS OF EXPERIMENTS

To determine the friction coefficient was used technique "Ball -on- Disc", whose principle consists in placing bodies in the form of non - rotating Si_3N_4 ceramic ball on the sample surface (disc-shaped). At a chosen distance from the center of the sample is ball loaded by a predetermined force. Disk (Figure 4) starts turning at a defined speed (revolutions per minute), and executes a predetermined number of revolutions. As a direct result of the measurement is a plot of the coefficient of friction depending on the distance (respectively speed).

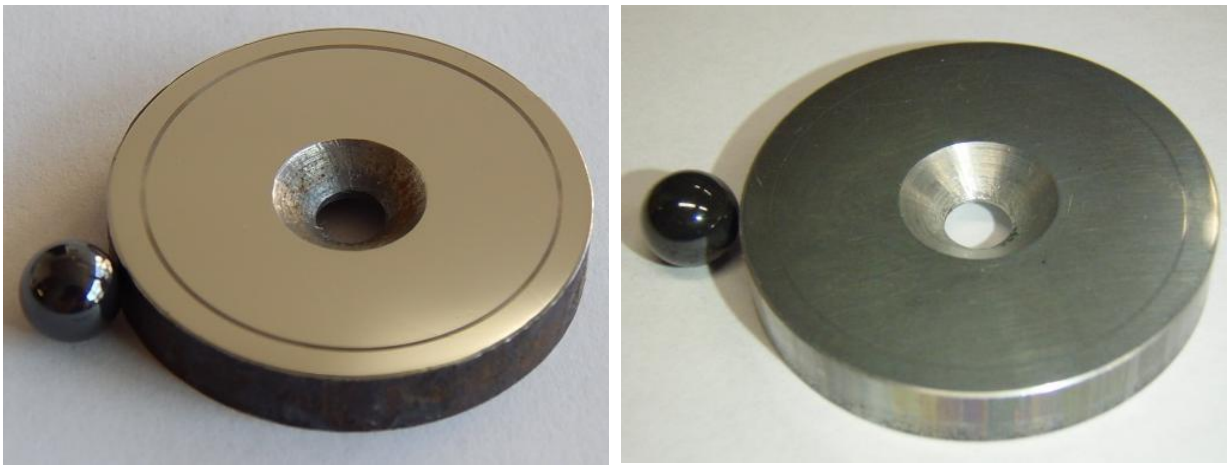

Fig. 4 Samples of steel 10084-94, aluminium EN AW 2030 and ball made of Si_3N_4 after the tribology measurement

Tribological tests were performed by using a 5% solution of the three different process fluids marked as PF 1, PF 2 and PF 3 (5 % solution is commonly used in the machining process). As the counterpart (ball) was used material Si_3N_4 (Figure 4) which has to imitate the friction pairs in case of coating tool during machining. Friction pair was immersed in 5% solution of process fluid.

The effect of process fluids on the friction coefficient in dependently on the track at 10N load and profile depth of crumbled grooves are shown in Figure 6. The study of the tribological behavior of process fluids during the tribological experiment using steel pads EN 10084-94 and ball made from Si_3N_4 is shown in Figure 5.

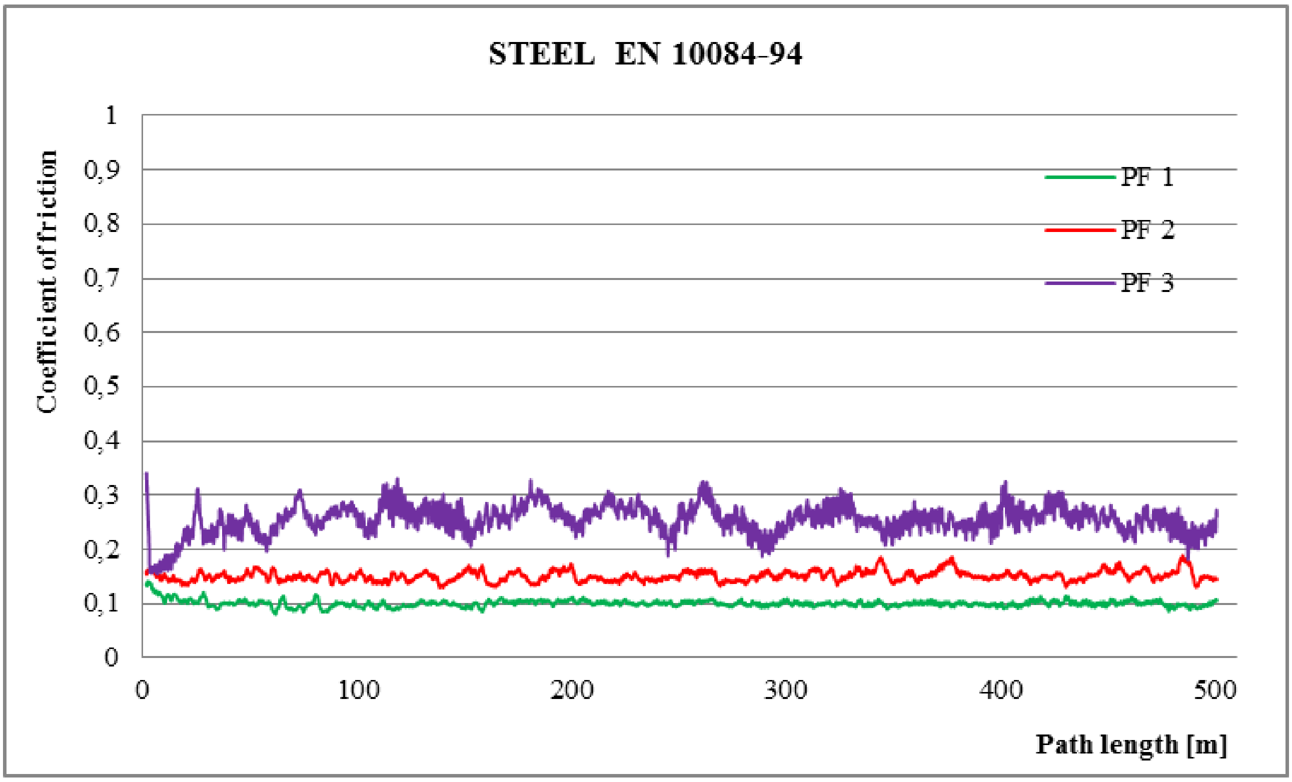

Fig. 5 Comparison of the coefficient of friction at the friction pair Si_3N_4/ steel EN 10084-94

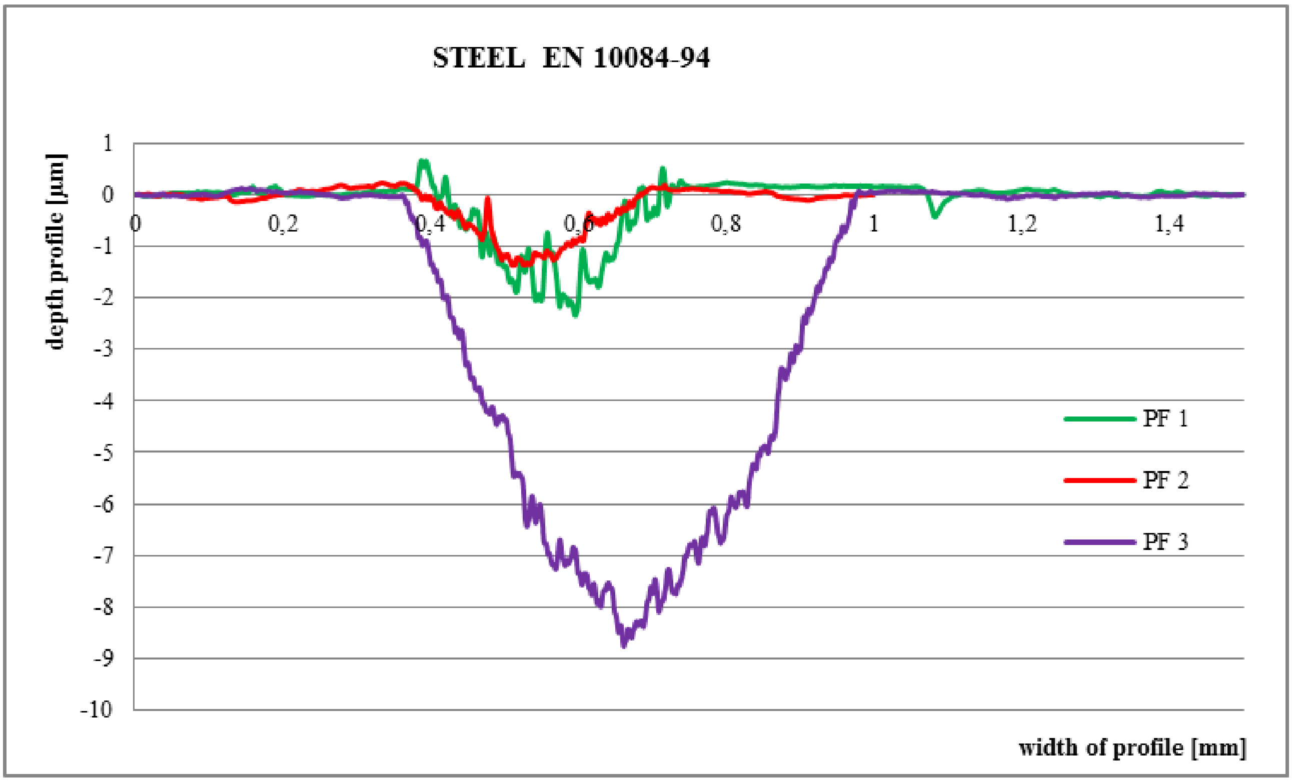

Fig. 6 Profile of the groove of the friction pair Si_3N_4/steel EN 10084-94

The effect of process fluids on the friction coefficient in dependently on the track at 10N load and profile depth of crumbled grooves are shown in Figure 8. The study of the tribological behavior of process fluids during the tribological experiment using steel pads ISO 683/13-86 and the balls made from Si_3N_4 are shown in Figure 7.

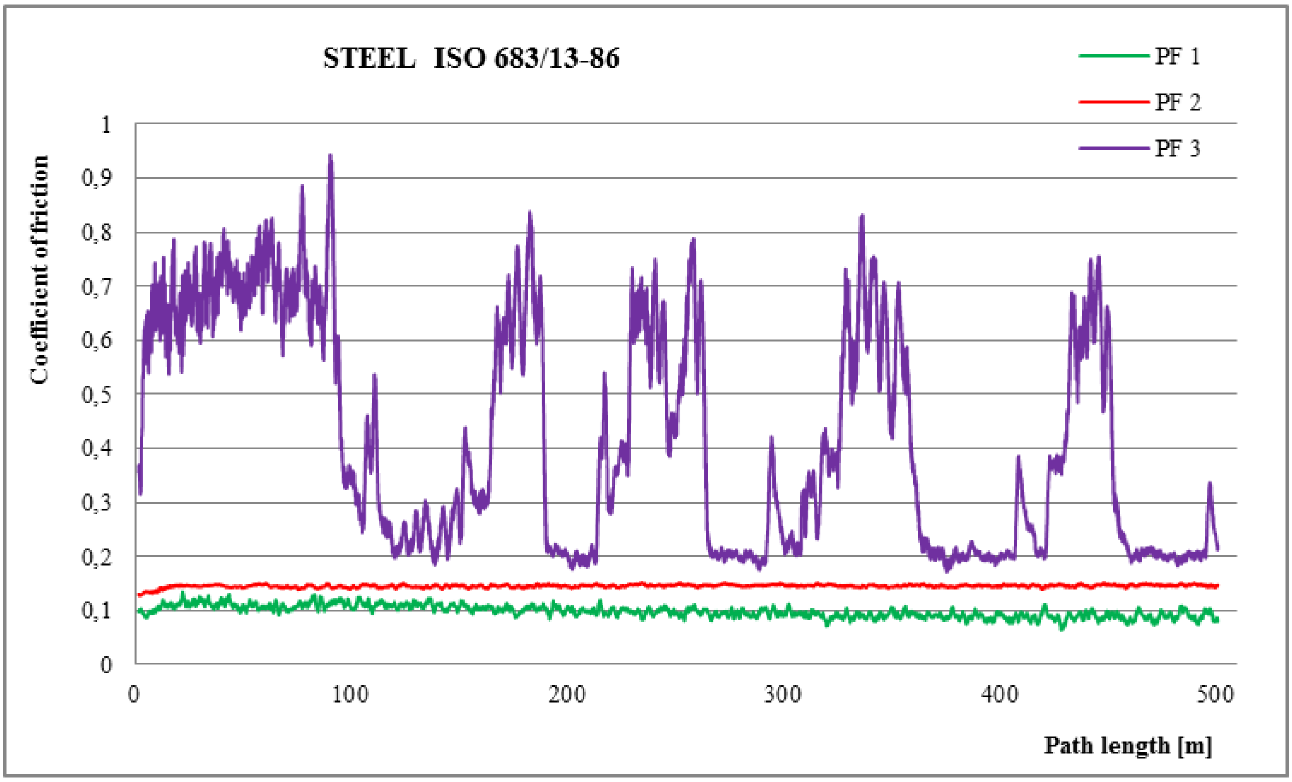

Fig. 7 Comparison of the coefficient of friction at the friction pair Si_3N_4/steel ISO 683/13-86

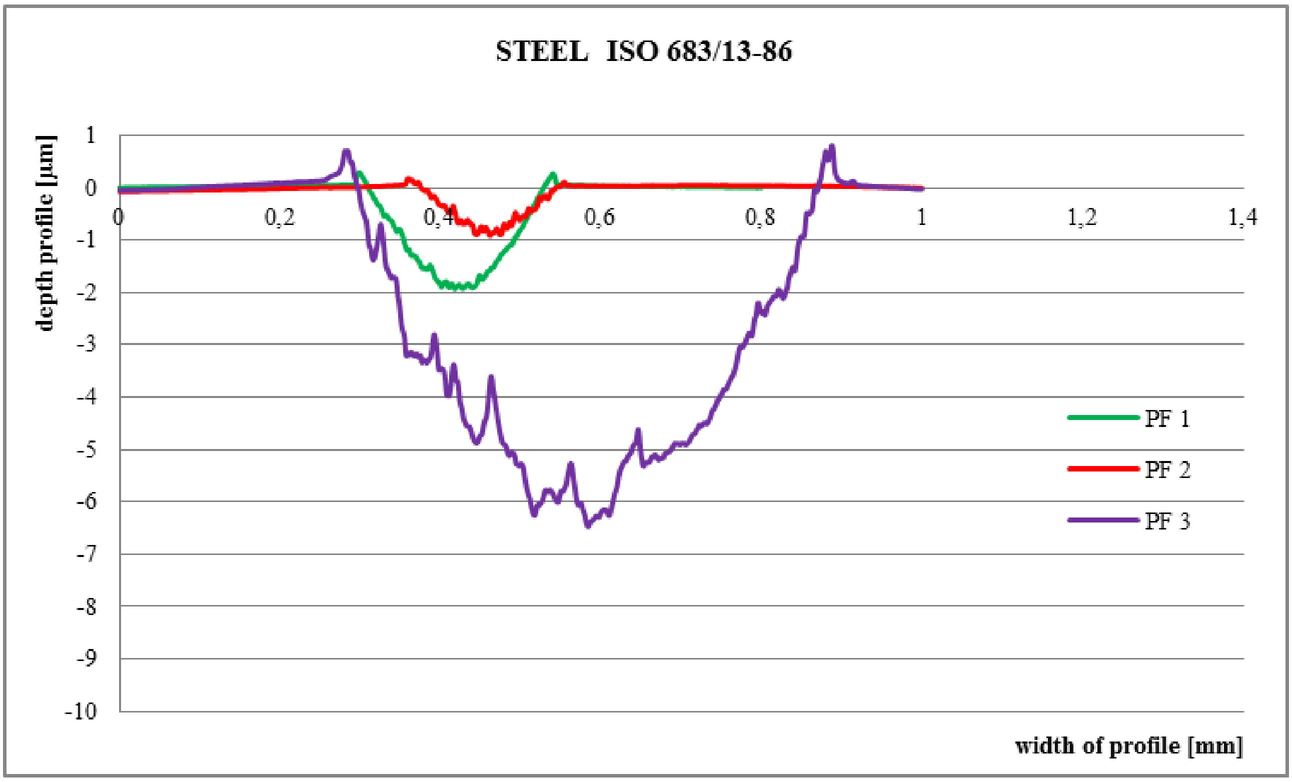

Fig. 8 Profile of the groove of the friction pair Si_3N_4/steel ISO 683/13-86

The study of the tribological behavior of process fluids during the tribological experiment using pads made of aluminum EN AW 2030 and balls made from Si_3N_4 is shown in Figure 9. The depth of the profile of crumbled groove is shown in Figure 10.

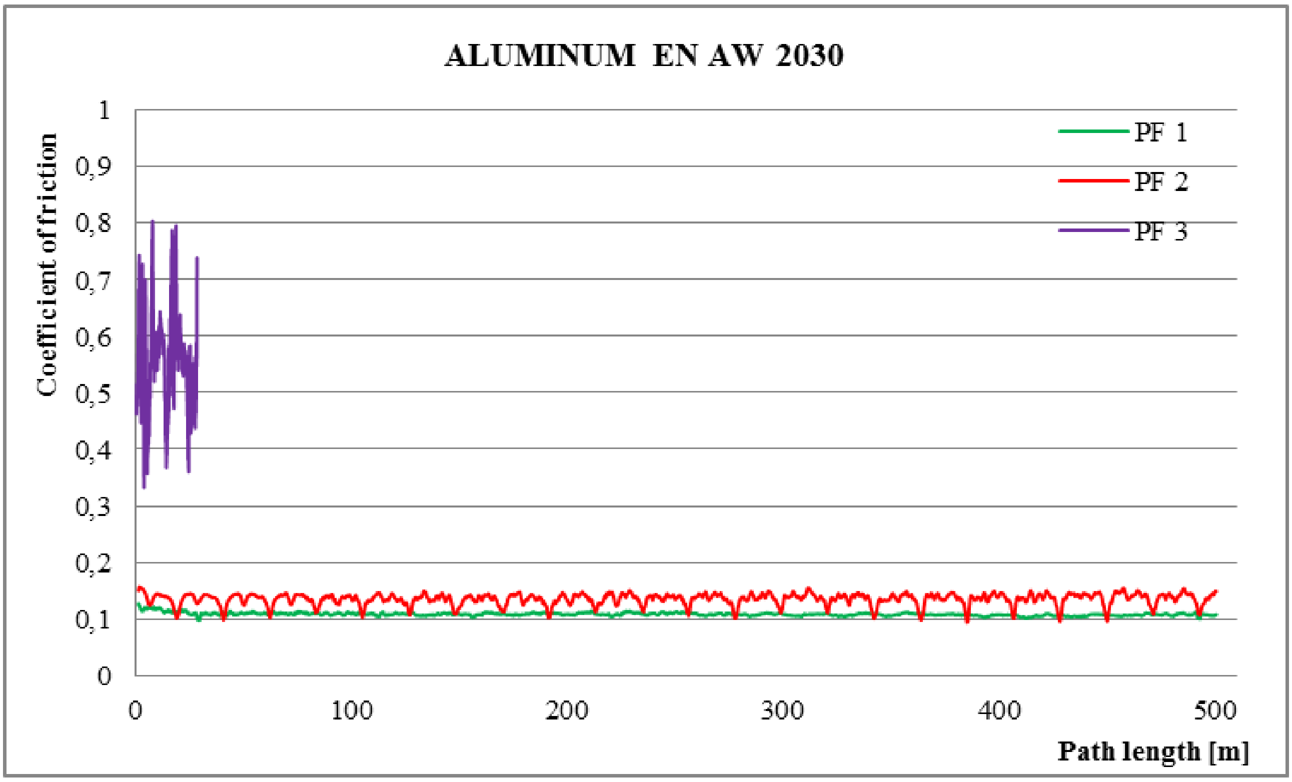

Figure 9 Comparison of the coefficient of friction at the friction pair Si_3N_4/aluminium EN AW 2030

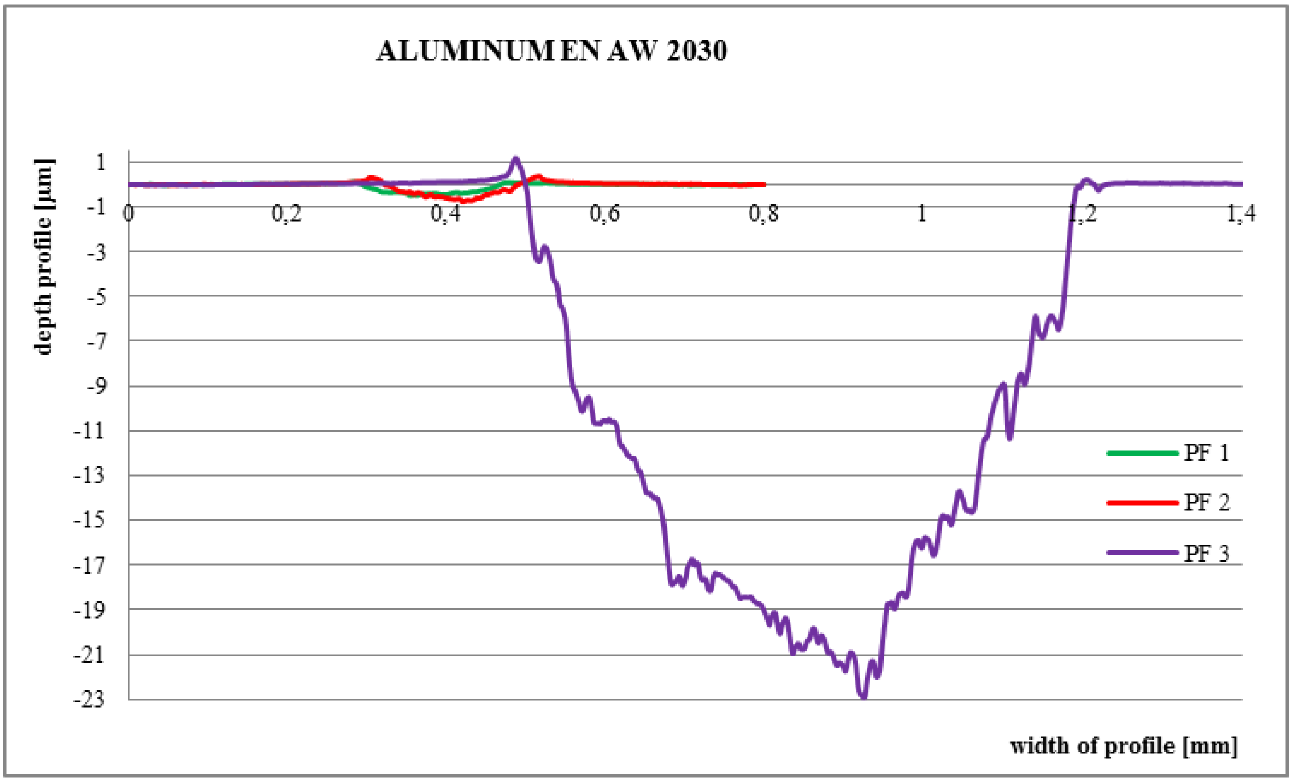

Fig. 10 Profile of the groove of the friction pair Si_3N_4/ aluminium EN AW 2030

During the implementation of tribological experiment was examined the coefficient of friction using the structural steel EN 10084-94, austenitic steel ISO 683/13-86 and aluminum EN AW 2030. For the comparison was used a 5% solution of the three different process fluids marked as PF 1 (based on vegetable oil), PF 2 (based on mineral oil) and 3 PF (synthetic PF), solutions are commonly used in the machining process. When determination of the coefficient of friction for friction pairs Si_3N_4/steel EN 10084-94 the best results were obtained with the PF -based vegetable oil marked as PF 1, wherein throughout the whole experiment was preserved value of 0.1 (Figure 5). Another important parameter is the material wear. For friction pair Si_3N_4/steel EN 10084-94 minimum depth of removed material was registered with the process fluid based on mineral oil which was marked as PF 2.

During the determinination of the coefficient of friction for the friction pair Si_3N_4/steel ISO 683/13-86, the process fluid based on vegetable oil marked as PF 1 and the process fluid based on mineral oil marked as PF 2 (Figure 7) were still preserved their positive impacts during the tribological process and equal depth of the profile of crumbled material for the friction pair Si_3N_4/steel EN 10084-94. Synthetic PF 3 has showed worse tribological properties. Also during the determinination of the coefficient of friction in case of friction pair Si_3N_4/aluminum EN AW 2030 were the best results again achieved with the process fluid based on vegetable oil marked as PF 1 and process fluid based on mineral oil marked as PF 2 (Figure 9). The synthetic process fluid marked as PF 3 showed only a low coefficient of friction but also a noticeable wear of material during the experiment. The reached depth of removed material was almost twice as much as at the beginning of the experiment, after the first 50 m experiment has to be stopped.

4. CONCLUSION

Process fluids, which were used in the tribological experiment had different basis and compositions. For all investigated friction pairs (Si_3N_4/steel EN 10084-94, Si_3N_4/steel ISO 683/13-86 and Si_3N_4/aluminum EN AW 2030) it was found out that the process fluid based on vegetable oil marked as PF 1 and process fluid based on mineral oil marked as PF 2 showed similar properties, differences showed the synthetic process fluids marked as PF 3. The grooves of the profiles of removed material proved better frictional properties in case of PF 1 and PF 2 under the set conditions. Better coefficient of friction and lower depth of the groove made by removed material after tribology suggest a better lubricating properties of the PF.

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Tribologické chování procesních kapalin při použití různých třecích dvojic

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Klíčová slova: tribologie, procesní kapaliny, třecí dvojice, koeficient tření, opotřebení

Abstrakt

Tribologie zahrnuje procesy vzájemného působení na rozhraní mezi pevnými, kapalnými a plynnými tělesy. Úkolem tribologie je zajistit, aby vzájemný pohyb dvou povrchů probíhal s co nejmenší ztrátou energie a materiálů. Tyto faktory charakterizují tribologické vlastnosti nově vzniklého funkčního povrchu s využitím lubrikantů. Tribologické vlastnosti popisují především koeficient tření a opotřebení, které závisí na typu tření a mechanizmu opotřebení.
Při zkoumání třecích projevů a účinků pohlížíme na soustavu tvořenou dvěma tělesy, jejich stykovými plochami a látkou, která je mezi nimi a okolím, jako na tribologický systém. Tření má značný vliv na technologické vlastnosti procesních kapalin a může vést ke snížení životnosti a změnu jejich funkčních vlastností. Životnost mazacích, chladicích, procesních kapalin je jedním ze základních aspektů, které určují kvalitu kapaliny, jejích působení při technologickém procesu a ekonomickou nákladovost.

Zpět