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Experimental investigation of oil pockets effect on abrasive wear resistance

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ABSTRACT

The experiments were carried out using a block-on-ring tester. The stationary blocks were modified by a burnishing technique in order to obtain surfaces with oil pockets of spherical shape. The area density of oil pockets varied in order to explore their effect on wear resistance and wear intensity. Specimen surfaces had dimples with depths 45–60 μm and diameters 1–1.2 mm. The area density of oil pockets S_p was in the range 4–20%. The block samples were made from bronze B101 (CuSn10P) of 138 HB hardness. The rotated rings were made from 42CrMo4 steel, hardness of 40 HRC obtained after heat treatment. The tested assembly was lubricated by mineral oil L-AN 46. The experiment was carried out under artificially increased dustiness conditions. The dust added to oil consists mainly of SiO_2 (74%) and Al_2O_3 (15%) particles. During the test friction force and temperature of block sample were registered. The tendencies of block surface topography changes during wear were analysed. It was found that sliding pairs with textured specimens were not superior to a system with a turned block with regard to abrasive wear resistance.

1. Introduction

Surface texturing is an option of surface engineering resulting in improvement in load capacity, coefficient of friction, wear resistance, etc. The oil pockets (micropits, holes, dimples or cavities) may reduce friction by providing lift themselves as micro-hydrodynamic bearings and/or by acting as reservoirs of lubricant. The dimples can be micro-traps also to capture pollutions and wear debris [1,2].

Various techniques can be employed for surface texturing including laser texturing, etching techniques and machining. It seems that laser surface texturing offers the most promising concept, because the laser is extremely fast, is clean to the environment and provides excellent control of the shape and the size of the texture [1].

The most familiar practical examples of textured surfaces include plateau-honed cylinder surfaces in combustion engines. Plateau-honed cylinder surfaces ensured shortening of the running-in and lower wear in this period [3]. Pawlus [4] found that the values of the local linear wear of cylinders with the same roughness height were proportional to the emptiness coefficient Rp/Rt. New cylinder surface structures that are generated by a modified honing process and a laser based material treatment represent a very promising approach for reducing both wear and friction losses without an increase in oil consumption [5]. It was found that volumetric wear of the laser-textured surface during running-in of 250 h duration of Volkswagen 5-cylinder engine was reduced by almost 25% in comparison to the standard plateau-honed surface. One can find similar report in Ref. [6].

A burnishing (embossing) technique is very promising in the creation of textured surfaces. The results of experimental investigations of the effects of oil pockets (created by burnishing technique) presence on the tribological performance of sliding elements under mixed lubrication conditions are presented in Ref. [7]. Surface texturing of the block surface (area density between 20% and 26%) resulted in significant improvement in wear resistance in comparison to a system with untextured samples. The result of investigations with steel shafts, finished by grinding and vibratory burnishing, contacting with a rubber sliding bearing showed that the burnished surfaces possessed about 64% higher wear resistance than ground samples [8].

Sliding contacts are often critical due to the performance of micromechanical assemblies. In order to improve localised liquid lubrication on a flat surface a special laser technique was employed to produce the microscopic patterns on highly polished, synthetic sapphire flats [9]. The effect of surface texturing on the sliding friction and wear properties was evaluated with a pin-on disc tribometer under the condition of minimal lubrication. The test results revealed that wear could be reduced and sliding life was significantly extended (compared to polished sample) by appropriate sizes and forms of micropatterns.

Textured surfaces with square depressions or parallel grooves were produced by lithography and anisotropy etching of silicon wafers [10]. Then the wafers were PVD coated with thin, wear resistant DLC coating, retaining the substrate texture. Under the starved boundary lubrication conditions, the most successful textures (with the smallest squares and grooves oriented

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perpendicularly to sliding direction) exhibited very low and stable friction as well as much better wear resistance than the untextured and less successful textured surfaces.

Textured surfaces can provide traps for wear debris in dry contacts subjected to fretting. The dimple existence could improve the fretting wear resistance [11] and almost doubled the fretting fatigue life [12]. Surface texturing was also successfully applied to mechanical seals resulting in increase in seal life [13].

Stepien [14] introduced dimples of 7–10 μm depth on the shaft surface co-acted with strip for tribologic stand simulating foil bearing. Lubricating oil was polluted by abrasive particles of sizes smaller than pits depth. It was found that surface texturing caused 3.6–5.7 smaller wear of the analysed assembly in comparison to smooth shafts [14].

Brake dust generated in vehicle brakes causes the emission of particles suspected of health hazard in the environment. The authors of [15] intentionally machined radial grooves (of 150 μm width and depth) into the disc that captured the wear debris. Pads rubbed against grooved discs experienced half the wear of those rubbed against smooth discs.

The experiments were carried out on a block-on-ring tester by Pawlus et al. [16]. The stationary block made from cast iron of 50 HRC hardness was ground. The rotated ground ring was made from 42CrMo4 steel of 32 HRC hardness. Oil pockets of spherical shape and of drop shape were machined on the ring surfaces. The pit-area ratios were in the range of 7.5–20%. The tested assembly was lubricated by contaminated oil with abrasive particles. Spherical shape of dimples was superior to drop shape with regard to wear resistance of steel rings. The reference ground rings (without oil pockets) were seized in the beginning of the test.

The grey cast iron cylinders of different surface topographies were tested during automotive gasoline engine operations under artificially increased dusty conditions [17]. Cylinders of pearlitic–ferritic structure showed the best abrasive resistance. These results can be explained by the possibility that quartz particles were embedded in the comparatively large graphite flakes located within the soft ferrite matrix. The influence of the cylinder surface topographies on their abrasive wear was also substantial.

It was found from literature review that surface texturing of one of the sliding elements can result in significant improvement of wear resistance in the presence of dust particles in comparison to a system with untextured parts. The oil pockets are traps to capture pollutions and wear debris, reducing abrasive wear. Such depressions should be large enough to trap and store the particles. However the role played by oil pockets presence in the lubricated contact zone under artificially increased dustiness condition is not yet completely clear, particularly for high particles concentration and various hardnesses of the co-acting parts.

The purpose of this research is to study the effect of bronze block surface texturing on abrasive wear of steel–bronze sliding pair in lubricated sliding.

2. Experimental details

The experiments were conducted on a block-on-ring tester. The tribosystem consists of the stationary block pressed at a required load against the ring rotating at a defined speed. Fig. 1 presents a scheme of the tested assembly. This tester can simulate some real practical machinery, particularly slide bearings.

The temperature of the block sample was measured at a distance of 2 mm from the interface using a thermometer with resistance temperature sensor Pt1000 of measuring uncertainty of 0.4 °C. The construction of the friction machine allowed to measure the friction force between ring and block by S-Beam Smart Loadcell force transducer with a measuring range of 2500 N. The error of measurement was 0.25% of the measuring range. The sliding was unidirectional.

The block was precisely turned to $17.5^{+0.05}$ mm radius. The block samples, made from bronze CuSn10P of 138 HB hardness, were modified using the burnishing technique in order to obtain surfaces with circular oil pockets. Percussive burnishing with electromagnetic drive was used. Machine utilises impulse method, using kinetic energy of working elements. Burnishing element acted as a hammer to form dimples on inner cylindrical surface. The arrangement of oil pockets depends on working parameters of the burnishing device but shape on burnishing element. Dimples can be created on inner cylinder surfaces of diameter 30 mm and length up to 85 mm. Before burnishing specimens were turned using CNC machine. Bulges or burrs created near dimples were not removed by machining because they disappeared from surface in the beginning of the test. The area densities of oil pockets S_p were 4%, 6.5%, 10%, 15% and 20%. Block sample surfaces had usually dimples with depths of about 60 μm and diameters of about 1.2 mm. Only the depth and diameter of sample with $S_p = 4\%$ were smaller (45 μm and 1 mm, respectively).

The size of the dimples found in technical literature is usually 10–50 μm and a depth of about some microns. However dimples of similar sizes to be tested in this work were also textured; see for example [18,19]. Journal bearing sleeves with oil pockets of comparatively large sizes are also commercially available. Large dimples depth can lead to accommodate a substantially larger volume of abrasive particles and wear debris, decreasing wear of block samples particularly for high concentration of hard particles in the lubrication oil.

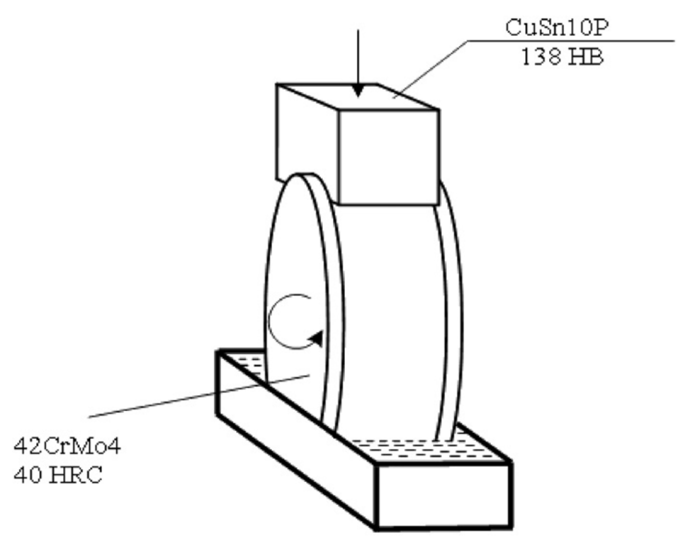

Fig. 1. Scheme of tested assembly.

Table 1
Parameters of L-AN 46 oil.

Parameters	Values
Kinematic viscosity in 40 °C (mm^2/s)	46.0
Kinematic viscosity in 100 °C (mm^2/s)	6.66
Viscosity index	96
Ignition temperature (°C)	Min. 170
Flow temperature (°C)	Max. −12
Density in 15 °C (kg/m^3)	880