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The use of nanomaterials to improve the wear resistance of machine parts under fretting corrosion conditions

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Abstract. The use of nanomaterials in different branches of machinery manufacturing has been studied. Nanomaterials application for improving working properties of machine parts has been described. Fullerene C₆₀ friction properties have been studied; the works of some authors on improving metal resistance with fullerene C₆₀ coating have been analyzed. It has been determined that there is little information about fullerene tribological properties and they are mostly about fullerene C₆₀ as a thin film and additive to lubricating materials in sliding friction with minor normal loads. The test results on fullerene C₆₀ impact as low-friction coating and additive to lubricating oil for reducing steel and brass samples wear in fretting corrosion are given.

1. Introduction

Improving operational properties and wear resistance of essential machine parts is acute for modern machine engineering. These problems are solved both at the stage of manufacture by improving production technologies and application of modern materials and protective and wear resistant-coatings [1, 2].

Among the works devoted to technological methods of improving operational properties the ones aimed at improving stability of cutting processes, materials and coatings should be mentioned [3-9].

Wide application of nanomaterials in machine building nowadays raises interest in their role as materials improving machine parts wear resistance. So, fullerene discovery resulted in its study in different aspects.

There is little information about fullerene tribological properties and they are mostly about fullerene C₆₀ as a thin film and additive to lubricating materials in sliding friction with minor normal loads. These conclusions can be grounded on general knowledge about C₆₀ molecules properties – their high elasticity and strength, low surface energy, high chemical stability, weak intermolecular interactions and a quasispherical form [10, 11].

C₆₀ can have perspectives for solving tribotechnological problems: application of solid films (in cutting tools, medical titanium parts, glass and ceramics, wearless sliding electric contacts and others). Fulleren application for formation of tribotechnic and tribochemical protective films on machine parts, internal surfaces of pipelines and reservoirs, anticorrosion protection; fullerene application with lubricants as multi-purpose additive to viscous lubricants, oils; as solid lubricant.

Fretting corrosion is one of wears. It appears during vibration of nominally immobile parts, when due to minimal friction amplitude wear products are not cleared from the contact zone, impacting significantly wear mechanism [1,2]. Carbonic and rust-resisting steels in friction couples steel-steel are



subjected to this type of wear (the couples may be of different types and similar), steel-tin, steel-brass, steel-aluminium, and cast iron-bakelite or chromium and other friction couples. Due to little displacement amplitude of contacting surfaces wears are concentrated mostly on little areas of the real contact. Wear products can not leave the contact zone, this results in pressure increase and their abrasive action on the metal.

Fretting-corrosion is often a damage reason of some important parts in internal combustion engines, in particular, large-capacity haulage trucks, drilling equipment parts and others, working in vibration conditions and high contact loads. Development of fretting-corrosion damages happens in large-sized steam and marine diesels on conjugation of external surface ("bearing lining") liners with crankshaft bearing seat, as well as during the contact of the cylinder liner jacket bearing surface with the frame bearing surface. These damages appeared on the conjugacy of the main crankshaft bearing cap lateral surface and a unit of diesel engines in large-capacity haulage trucks. Holes and corrosion products also appear on conjugant shaft surfaces and pressed to them discs, wheels, sockets and bearing races in thread and rivet joints and so on. These damages appear in wire cables, swithes, cut-off swithes and socket outlets.

There are no universal methods against fretting-corrosion. Protective coatings are mostly used for this purpose. Choosing protective coating materials for high-load assemblies from fretting-corrosion wear-resistance, shear sensitivity should be taken into account that is materials' ability to receive shear deformation without activating fatigue damage. Rather thin coatings have this property, which are convenient in that they keep up with the maintainability of joints and keep tensions prescribed in the assembly while in service [12]. Here nanomaterials, in particular, fullerene C_{60} , may be of interest, as their ability to resist fretting-corrosion has not been sufficiently studied yet.

The purpose of our study was testing fullerene C_{60} as material minimizing sliding friction wear in fretting conditions.

2. Materials and methods

The samples were tested on a special installation working on the drive of a standard friction machine (Figure 1). Immobile sample 1 was a disc 35 mm in diameter and thickness 7.5 mm. A mobile sample 2 was a quill cylinder with external and internal diameters 25 and 20 mm, which contacted by its end surface with the flat surface of a sample 1. Here, thanks to the cam mechanism the cylinder completed swinging movement round its axis, creating a circular friction path on the surface of the immobile sample. A load was applied along the axis creating the predetermined pressure on the contact.

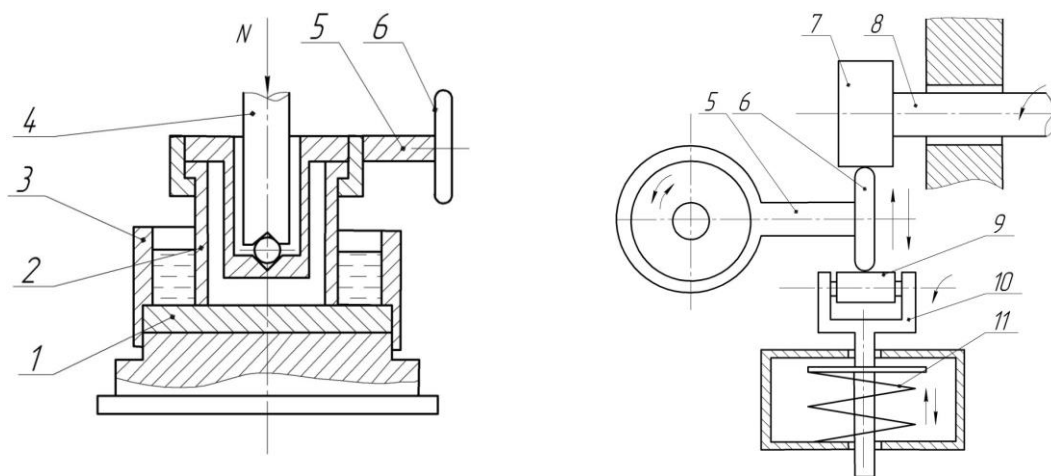


Figure 1. Friction machine set up plan: 1 – immobile sample, 2 – mobile sample, 3 – a mesh for process fluid, 4 – clamping stock, 5 – gearshift linkage, 6 – roller, 7 – cam, 8 – driving shaft, 9 – pressure roller, 10 – male, 11 – spring.

20 steel mobile samples and LAZH60 brass samples were tested with 20 steel immobile samples with fullerene C_{60} , added to liquid and consistent grease with the content of 2.5% after intensive mechanical mixing, and as brass sample coating. Test conditions were as follows: amplitude of oscillation was 150 mkm, cycle frequency 500 cycles/min, normal load in tests with lubricant was 4.2 MPa, and without lubricant was 3.2 MPa. Three similar samples were tested in similar testing conditions. Sample wear was determined by weighing on electronic scales with precision 0.1 mg before and after the test. The mobile samples were lubricated and the immobile ones were not.

3. Discussion of research results

Test results of fullerene C_{60} are in Figure 2 for steel samples and counter-samples in Figure 3 for brass samples and steel counter-samples show that introduction of powder (2.5%) into liquid lubricant decreases the fretting-corrosion significantly. Here similar introduction of powder into the grease was efficient only for the combination of brass and steel samples, that may be caused by its high viscosity and insufficient mechanical stability in shear deformations. In some cases there was a transmission of wear particles onto the studied counter-body, which is evidenced by negative wear values. But in this type of C_{60} introduction into grease decreased the wear in comparison with the oil without the additive.

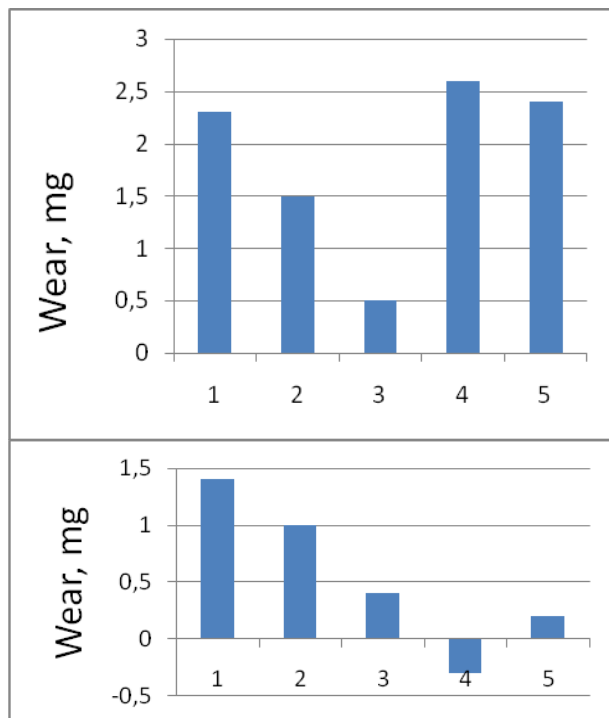


Figure 2. Wear of steel samples and counter-samples: 1 – unlubricated, 2 – VITREA 68 (SCHELL) oil, 3 – VITREA 68 (SCHELL) oil with 2.5% C_{60} , 4 – ALVANIA EP2 (SCHELL) grease, 5 – ALVANIA EP2 (SCHELL) grease with 2.5% C_{60}

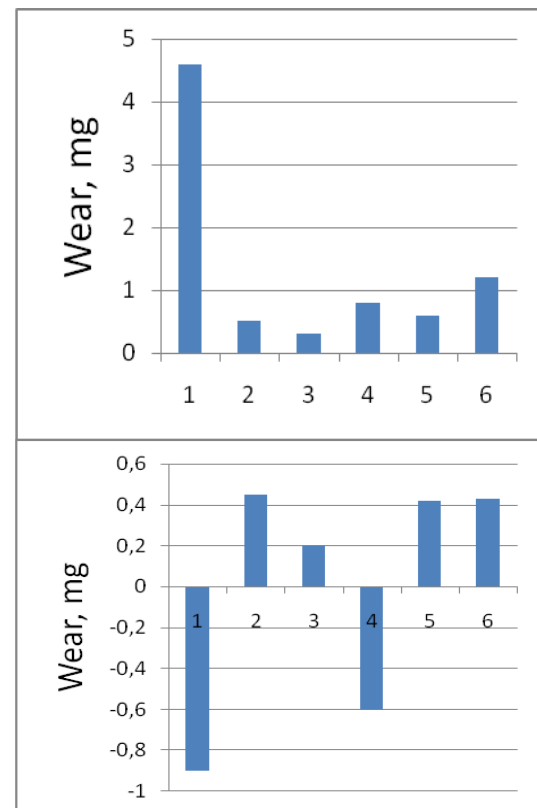


Figure 3. Wear of brass samples and counter-samples: 1 – unlubricated, 2 – VITREA 68 (SCHELL) oil, 3 – VITREA 68 (SCHELL) oil with 2.5% C_{60} , 4 – ALVANIA EP2 (SCHELL) grease, 5 – ALVANIA EP2 (SCHELL) grease with 2.5% C_{60} , 6 – C_{60} coating on a brass sample, dry friction

Brass samples testing with C_{60} lubrication showed that in unlubricated samples and without coating

at normal pressure 4.2 MPa there was clamping, and counter-sample rotation visibly decreased. It required load decrease to 3.2 MPa. In brass sample with coating there was no decrease in rotation. Wear of the coated brass sample was 3 times less than the wear of non-coated sample, due to lubrication absence, there was no cuprum transfer onto the counter-sample. This allows making a preliminary conclusion that these coatings are effective as grease, especially in cases when introduction of liquid lubrication to the friction part is difficult.

4. Conclusion

Application of fullerene C₆₀ as additive to liquid lubrication and grease as well as sample coating results in fretting-corrosion decrease of steel and brass samples, though its application is restricted in high contact loads. The conducted tests prove the prospects of fullerene C₆₀ application in conditions of fretting-corrosion.

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