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NEW GENERATION TRIBOLOGICAL DLC COATINGS[1]

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Abstract

In the presented paper a possibility of new diamond like carbon (DLC) coatings-orientants using is considered for some triboengineering applications. Orientation effect of coatings under consideration on molecular ordering in boundary lube layers and correspondingly, lubricity improving, which was established early on some model oils, now is demonstrated as applied to commercial lube oils and cutting fluids in gyroscopes and extrusion tread instrument.

Key words: DLC coatings; Coatings-orientants; Molecular orderings.

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1 INTRODUCTION

Practically all lubricated friction units operate periodically or permanently under conditions of boundary lubrication. Lubricating action here is provided by thin boundary layers formed in the result of interaction between the surfaces of rubbing elements and active ingredients of lube medium (adsorption, chemisorption, chemical reactions, etc.). The boundary layers have reduced shear strength in comparison with metal substrate. Separating rubbing surfaces they minimize metallic contact resulting in high wear and scoring.[1]

Boundary layers formed due to chemical interactions on the surfaces are effective in more wide range of operating conditions (loads and temperatures), but for their formation it is necessary to use chemically active additives (EP additives), which are not always acceptable accordingly operating conditions and/or ecological requirements.[1,2]

Efficiency of adsorbed boundary layers in rather wide ranges of operating conditions can be improved taking into account the fact that molecular orientation in interface lube oil – solid surface reproduces the orientation in surface layer of the solid, which adsorbs the lube oil.[3-5] Among the surface coatings for triboengineering application it is worth mentioning carbon diamond like coatings. These coatings demonstrate rather wide range of mechanical and tribological properties determined by their structure and the technological parameters.[5,6] At present time the above coatings are used in micro- and nanomechanical systems (MEMS and NEMS), medical industry, etc. It is found that surfaces with homeotropic orientation demonstrate the most evident effect on lube ELC layers.

It was shown that coatings of linear-chain two-dimensionally ordered carbon are excellent orientants.[7,8] The level of orientation effect and properties of such coatings depend strongly upon synthesis conditions, i.e. can be tailored in the process of manufacturing. During the deposition carbon chains are oriented homeotropically perpendicularly to the surface of the substrate and have a good adhesion to the surface. The hardness of carbon films varies from 6000 to 9500 HV. The model of the atomic crystal structure of the oriented carbon films sees Figure 1 can be presented as follows. The film is composed of parallel linear carbon chains densely packed into a hexagonal lattice.

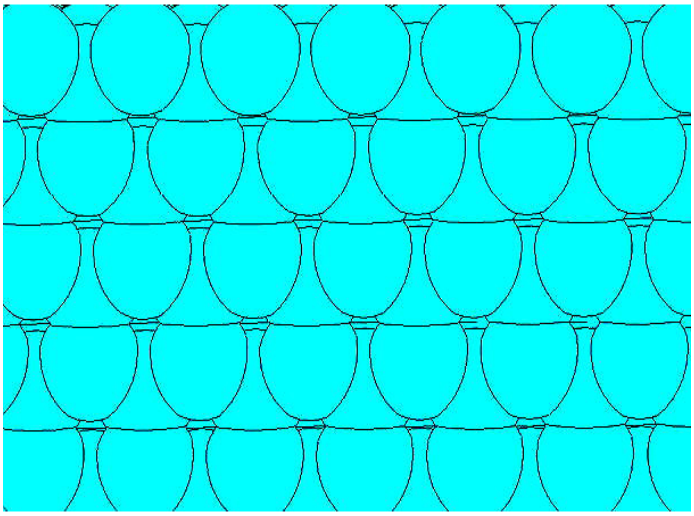

Figure 1. Model atom structure of carbon polymer.

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The authors have made a number of theoretical and experimental studies on coatings-orientants synthesis and analysis of their structure, tribological tests of coatings taking into account dependence of tribological characteristics upon the mentioned factors (the triad "structure- properties-parameters of synthesis"). The requirements to the mechanical, physical and chemical properties of coatings-orientants for triboengineering application were also formulated. The objectives of the present paper are to study the orientation effect of carbon coatings-orientants on friction behavior and lube ability of boundary layers as applied to some commercial lube oils and cutting fluids in gyroscopes and extrusion tread instrument**.**

2 MATERIALS AND EXPERIMENTAL PROCEDURE

As a surface orientant carbon monocrystalline linear-chained coating (M-carbon) was used. The coating was deposited by impulse condensation (τ = 400 μs, v=3,0 Hz) of carbon plasma ($\rho=10^{13}cm^{-3}$, degree of ionization is 95%) at additional radiation treatment by Ar^{+}.(3,4)

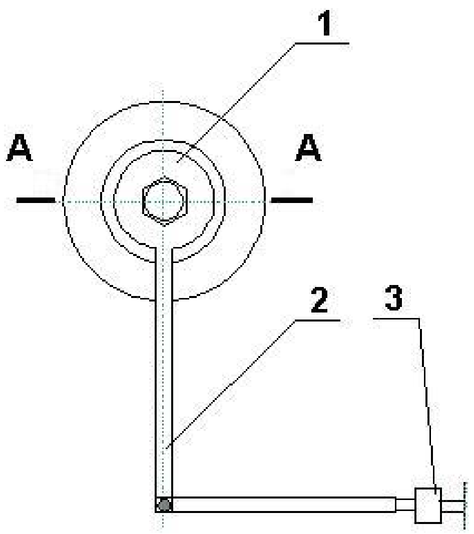

Figure 2. The scheme of test assembly.

The coating was deposited on the worktop of shipless taps (burnishers) M8 x 1,25 made of high-speed steel. The thickness of the coating was of 2 μk. The taps under study are used for internal thread forming. As metal working fluids the commercial technological mixtures based on mineral oil with some functional additives (F1) and water-based ones with addition of surfactants (F2) were used.(9) The comparative evaluation of torsion torque under tread forming and surface roughness was done for two process fluids. This value can characterize efficiency of tested coatings. As reference specimens the taps with standard chromium coating and without coating were tested. Test assembly was mounted on vertical drill 2C132 Figure 2. Spindle speed ranged from 45 till 1400 rev/min. The forces arising in the process of tread forming were registrated by strain gauge transducer connected with computerized dynamo-metering system. Test assembly consists of holder 1 for billet of screw nut 5, tread tap 4, lever 2 and force transducer 3, which allow transfering and registering forces appearing in the process of tread forming.

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The torsion torque was calculated as Mcr = Pmax·d, where Pmax is maximum force of thread forming, ·d – the distance between testing tap axe and force transducer fixing point.

3 RESULTS AND DISCUSSION

The test results for materials under consideration are given in Tables 1 and 2. The data presented in the tables are mean values from three separate tests.

Table 1. Torsion torque dependence upon thread forming speed. Metal working fluid F1 (mineral oil-based)

Thread forming speed v, m/s	Torsion torque M, Nm		
	Uncoated steel	Steel with chromium coating	Steel with carbon M-coating
0.104	5.25±0,03	5.2±0,03	4.55±0,03
0.208	5.8±0,03	5.55±0,03	4.6±0,03
0,296	Jamming	5.55±0,03	5.0±0,03
0.417		5.55±0,03	5.5±0,03
0.583		6.0±0,03	5.3±0,03

Table 2. Torsion torque dependence upon rate of tread forming for tested materials and coatings. Metal working fluid F2 (water-based)

Thread forming speed v, m/s	Torsion torque M, Nm		
	Uncoated steel	Steel with chromium coating	Steel with carbon M-coating
0.104	3.7±0,04	6.4±0,04	4.1±0,04
0.208	3.7±0,04	5.6±0,04	4.0±0,04
0,296	3.6±0,04	5.6±0,04	3.5±0,04
0.417	12.25±0,04	6.4±0,04	3.45±0,04
0.583	Jamming	8.25±0,04	3.25±0,04

According to the data given in Tables 1 and 2 the taps coated by carbon M demonstrate minimal values of torsion torque for both types of working fluids and correspondingly better effectivity as compared to chromium coating and uncoated high-speed steel. While operating with metal working fluid F1 at thread forming speed v=0,296 м/с and higher the billet metal balling on uncoated taps occurred what resulted in screw nut jamming. The effect of torsion torque decreasing is more evident for water-based working fluid F2 Besides for this fluid one can see a trend to torque decreasing with thread forming speed growth.

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Figure 3. Sliding bearings for gyrocompass with monocrystalline carbon coating.

For chromium coating and uncoated steel an opposite trend occurs, i.e. torque value increasing with speed. Maximum difference in torsion torque values takes place at higher speeds. Comparing the obtained results it is possible to conclude that polar water-based metal working fluid with surfactants in more extend is inclined to form highly oriented boundary layer on the surface of coating-orientant in comparison with oil-based fluid. The carbon coating under study was also used in sliding bearing of gyrocompasses lubricated by industrial mineral oil Figure 3. Tests of gyrocompasses with carbon M-coating had shown increase in service life in 2, 5 times in comparison with traditionally used uncoated bearings.

The results of pilot tests with commercial lubricating fluids presented in the paper prove the developed by authors concept regarding orientating effect of some solid surfaces and surface coatings on structural ordering and correspondingly on lubricating properties lube oils and metal working fluids.

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