New generation carbon coatings with monocrystalline structure as the promising new method of oil lubricity increasing

V. Levchenko[1,*], I. Buyanovsky[2], K. Zakharov[2], A. Bol'shakov[2], V. Matveenko[1]

[1)] Department of Colloid Chemistry, Lomonosov Moscow State University, Leninskii Gory 1, Moscow, 119991 Russia.
[2)] Department of tribology, Blagonravov Mechanical Engineering Research Institute, Moscow, Russia.

*Corresponding e-mail: vladalev@yahoo.com

Keywords: Monocrystalline carbon coatings; DLC coatings-orientants; boundary lubrication

ABSTRACT – New generation carbon coatings with monocrystalline structure are proposed for using in tribounits of heavy loaded machines and apparatus operating under conditions of boundary lubrication**.** These coatings allow increasing essentially antifrictional characteristics of lube oils without triboactive additives or enlarging temperature range of lube oils efficiency under boundary lubrication. Effect of the coatings under consideration on oil tribological properties is explained by reproduction of the solid substrate orientation i.e. highly ordered monocrystalline carbon in oil boundary layer, that allows forming strong boundary layers composed of homeotropically oriented molecules with increased temperature stability. Contrary to monocrysta-lline carbon coatings amorphous ones do nor display remarkable orientating effect and correspondingly have no influence on lube ability of studied oils.

1. INTRODUCTION

It is known that more than 30% world generated energy is expended for overcoming friction in machines. This results in increased fuel consumption what in present-days is connected with nonrenewable natural resources outlay. The tendency to reduce these losses leads to development of lube oils providing energy and resource saving due to friction losses and concomitant wear reducing by optimization their viscous-tempera-ture properties and by introducing in oils compositions a complex of additives. As a rule diesel oils include from 6% to 25% and transmission oils - from 8 to 12% additives (including 5..7% special additives increasing oil lubricity). A significant part of these additives are rather expensive, besides many additives contain compounds which pollute environments [1,2]. It is also known that efficiency of lube oil action in great extend depends on the level of orientation of their active compounds on rubbing surfaces. At the same time the orientation of oil molecules in boundary layer reproduces the orientation of the solid surface where this layer is formed [3]. A logical consequence of this situation is to develop coatings with highly ordered structure providing high level of molecular ordering in lube boundary layers what will result in increased lubricity of boundary layers. Besides these coatings should have rather high wear resistance. So, development of wear resistant coatings with orientating effect is possible consider as one of the promising ways to reduce friction losses in movable friction units and correspondingly to increase service life and coefficient of efficiency of machines and mechanisms.

On this point seems promising application of diamond-like carbon coatings having distinct orientating properties. It was found that the coatings of two-dimensional ordered plane-chained (monocrystalline) carbon are excellent orientants for forming hydrocarbon structurally-ordered epitropic liquid phase (ELP) on their surface [4]. In addition these coatings are very hard and wear resistant.

The objectives of this work is to analyze the results of comparative tribological tests of uncoated steel specimens and ones coated by carbon with and without distinct orientating properties both in a model inactive oil (i.e. the oil which practically do not reveal lube activity) and in this oil with some surface-active additives, and evaluate antifriction characteristics of these oils.

2. EXPERIMENT AND RESULTS

The new technology of carbon (monocrystalline and amorphous) deposition on steel surfaces by impulse condensation of carbon plasma was developed [3–7]. For tribological studies a test device "ball-on-disc" [1] was used. Tests were carried out by the method of Bol'shakov et al.[1] under constant load of 7.4N and constant low velocity of relative shift of specimens (0.01mm/s). Temperature of friction elements and oils under test was increased by an external heat source. Tests were carried out in temperature range 20 to 150^{0}C. As inactive oil pure liquid paraffin was used. Test results are presented in Tables 1 and 2.

Table 1 Effect of temperature and type of carbon coating on friction coefficient under tests in pure liquid paraffin (inactive oil).

Disc coating	Oil	Temperature, ^{0}C			
		20	50	100	150
Uncoated	Pure liquid paraffin	0,19	0,18	0,17	0,21
Monocrys-talline carbon		0,10	0.06	0,09	0,12
Amorphous carbon		0,24	0.25	0,23	0,23

NOTE: friction pair: ball-disc (hardened low chrome ball-bearing steel); load –7.4 N; speed – 0.01mm/s, rate of temperature rise – 100^{o}C/min.

Table 2 Effect of test temperature, additives to inactive paraffin oil and type of carbon coating on friction coefficient.

Disc coating	**Additive**	**Temperature,^{0}C**			
		20	**50**	**100**	**150**
Uncoated	0,1% SA	0,12	0,11	0,10	0,22
	1,0% OA	0,14	0,12	0,10	0,24
Monocrystal line carbon	0,1 % SA	0,10	0,10	0,10	0,12
	1,0% OA	0,08	0,08	0,05	0,03
Amorphous carbon	0,1% CA	0,18	0,17	0,16	0,16
	1,0% OA	0,30	0,30	0,20	0,20

NOTE: Friction pair ball–disc (hardened low-chrome ball-bearing steel); load – 7,4 N; speed – 0,01 mm/s, rate of temperature rise – 10^{0}C/min. Base oil –pure paraffin; Additives: SA–stearic acid, OA -oleic acid.

The data of experimental studies in the model inactive oil (paraffin) show that deposition of a thin layer of monocrystalline carbon (thickness of 1-2µm) on the surface of one rubbing element results in essential friction reducing in all the range of test temperatures as compared with uncoated specimens On the contrary the amorphous coating demonstrates higher friction under considered conditions in comparison with both uncoated specimens and monocrystalline carbon (Table 1).

Tests of the inactive oil with surface-active additives (oleic and stearic acids) have shown better friction characteristics of monocrystalline carbon coating as against to uncoated steel and amorphous carbon. It is also possible to see that monocrystalline carbon provides operating temperature range widening both for inactive base oil itself and for this oil with surface-active additives, what follows from down coming temperature dependence of friction coefficient and its low values at high temperatures (Table 2). On contrary amorphous carbon coating does not display such effect; moreover it makes worse oil lube ability compared with uncoated steel. Some machine parts with working surfaces coated by monocrystalline carbon are presented in Figure 1.

a b

Figure 1 Appearance of some machine parts with monocrystalline carbon coating: a– ball bearing (disassembled), b - micro-bearing.

Thus, it is possible to conclude that monocrystalline carbon coatings-orientants on steel surfaces increase essentially lube ability of oils both inactive and those having definite lube activity.

3. SUMMARY

The results of experiments have shown that the values of friction coefficient and the friction dependence via temperature are determined by the type of coating and its orientation properties. The difference in friction characteristics is connected with the different degree of orientation of molecules ELC in boundary lubricating layers on rubbing surfaces. Neither steel nor amorphous diamond-like coatings are not structural orientants. On the contrary carbon monocrystalline coatings increase the degree of molecular structural ordering in the boundary lubricating layers and consequently their lubricating ability. The monocrystalline coatings-orientants can improve lubricating properties of oils (with and without additives) and may be advantageous for engineering practice as they improve antifriction characteristics of rubbing pairs and allow controlling the processes of boundary lubrication. Thus, received DLC monocrystalline coatings-orientants can be today the best materials of green tribology.

4. REFERENCES

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