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Influence and Effectiveness of Lubricants on Friction on the Surface of Materials

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Abstract: *This article discusses the phenomena occurring in the zone of interaction of surfaces during friction and wear of lubricants in the presence of various liquid and gaseous media, as well as the analysis of the effectiveness of lubrication on surfaces during friction.*

Keywords: *friction, mechanical impacts, corrosion - mechanical, electrical impacts, polymer, metal, graphite, cracks, destruction, corrosion damage, boundary lubrication, semi-fluid lubrication, liquid lubrication, babbitt.*

Phenomena and processes occurring in the zone of interaction of surfaces during friction and wear in the presence of various liquid and gaseous media are diverse and complex. In the areas of actual contact of rough surfaces, enormous specific loads act, determined in the limit by the hardness of the materials in contact. With boundary lubrication, the pressures are only slightly redistributed. Only under the conditions of hydrodynamic or elastohydrodynamic lubrication, the load in the rubbing interface is distributed more evenly over the nominal contact area.

The problems of friction, wear and lubrication are complex. They closely intertwined the interests of various fundamental and applied sciences: mechanics, physics, physical chemistry, chemistry, materials science, the theory of strength and plasticity, etc. very rapidly changing non-equilibrium conditions.

The running-in process takes a short period of time and is characterized by increased surface activation, wear intensity and heat release, which leads to physical and chemical changes in the surface layers and the creation of equilibrium roughness. As a result of running-in, a complex of favorable properties is developed in the system, which determines the maximum bearing capacity of the rubbing interface.

Types and characteristics of wear are determined by GOST 23.001-77. There are mechanical wear that occurs as a result of mechanical influences; corrosion-mechanical, when, in addition to mechanical, chemical or electrical influences act; and abrasive. Abrasive (mechanical) wear occurs as a result of the cutting or scratching action of solid particles in a free or fixed state. Varieties of mechanical wear are also fatigue wear, the initial stages of fretting corrosion, etc. When exposed to a liquid or gaseous medium and abrasive, hydroabrasive or gas-abrasive wear is distinguished, and without the determining action of abrasive particles, erosion wear.

It is not uncommon for machine parts to operate under cavitation conditions. Wear in this case, called cavitation wear, occurs when gas or vapor bubbles (caverns) collapse near the surface of the part, which creates a local increase in pressure or temperature, leading to the separation of wear particles and the destruction of surface layers.

A large number of tribocouples operate under current collection conditions. In this case, electroerosive wear of friction surfaces occurs as a result of the impact of discharges during the passage of an electric current.

The effectiveness of lubricants (liquid and plastic) in preventing the manifestation of seizure of rubbing surfaces can be increased: by introducing into lubricants surface-active, reactive and full-forming additives that promote the formation of strong protective films on surfaces directly in the process of friction; the introduction of finely dispersed solid substances (graphite, chalcogens, metals, polymers, etc.) into lubricants, preventing direct contact of friction surfaces; providing structural measures with hydrodynamic or hydrostatic friction conditions (surfaces are separated by a layer of lubricant). The latter also applies to the case of gas (gas-dynamic and gasostatic) lubrication. In some cases, the manifestation of seizure can be eliminated by the use of gaseous chemically active media that form or promote the formation of protective films on surfaces that prevent seizure (to a large extent, this role is played by atmospheric oxygen).

We will consider the patterns of wear of some tribosystems on the example of plain bearings of crankshafts of various engines. Wear and damage of such bearings are determined taking into account the mode and operating temperatures (Table 1).

Under liquid lubrication, the wear intensity is negligible and wear is mostly due to the ingress of abrasive particles. For rubbing units, the mixed friction mode is typical, when there are areas of both liquid and boundary lubrication. Such a regime often occurs due to an increase in pressure and temperature, and sometimes due to a change in the geometric shape of the bearing as a result of its wear, which, in particular, is observed in backlash-free plain bearings of freight cars.

Table 1. Types of damage to plain bearings.

Fluid friction mode	Mixed or boundary friction mode	No lubrication
Fatigue damage (cracks, spalling, fractures)	Fatigue damage (cracks, spalling, fractures)	Seizure wear accompanied by tearing and transfer of metal from one surface to another
Wear due to abrasive action of particles entering with the lubricant	Wear due to abrasive action of particles and seizing in certain areas of surfaces	The formation of deep and wide grooves, leading to scuffing of rubbing surfaces
Cavitation damage to liners (local and general over all or most of the surface)	The formation of deep and wide grooves, leading to scuffing of rubbing surfaces	
Corrosion damage (general or individual structural components)		Wear due to crushing (plastic deformation of rubbing surfaces)

The bearing capacity of such bearings, taking into account the wear of the babbitt layer and operating conditions, is determined by the criteria of the thickness of the oil layer, pressure and the product p , speed and initial diametral clearance A.

When an increased wear of the journals of the shafts and bearings is detected and the presence of a sour cream lubrication regime is determined using calculations and appropriate experiments, ways are found to transfer to a liquid lubrication regime. In accordance with the Gersey-Striebeck diagram (Fig. 1), the formation of such a regime (section 3) is possible due to an increase in the viscosity of the lubricant, angular velocity, and a decrease in pressure. It is sometimes possible to soften the working conditions of the tribosystem with the help of structural changes in rubbing parts. For example, the groove less design of the crankshaft bearings of diesel locomotives made it possible to transfer the operation of such bearings to the liquid lubrication mode, eliminate the cases of scuffing of the crankshaft journals and significantly increase the durability of the rubbing assembly.

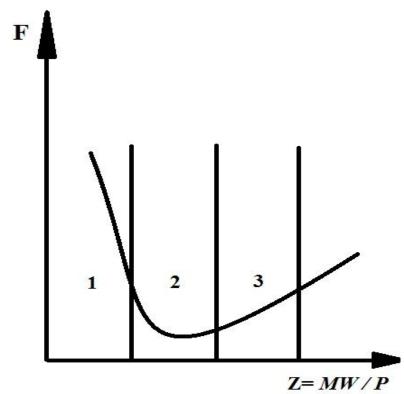

Fig. 1. Change in the coefficient of friction from the complex Sommerfeld parameter (Gersey-Striebeck curve):

1 – zone of boundary lubrication; 2 - zone of semi-liquid lubrication; 3 - zone of liquid lubrication.

In cases where it is not possible to transfer the operation of the tribosystem to liquid lubrication conditions, it is necessary to find ways to ensure stable operation even in a mixed lubrication regime. This is achieved by the selection of lubricants (and additives to them), anti-friction materials and trunnion materials. When choosing a lubricant, it is necessary to focus on lubricants in which the transition from the hydrodynamic mode to the discontinuity mode occurs at a higher temperature. The latter is achieved by introducing into the lubricant a certain amount and composition of surfactants (additives), as well as additives of various metal particles (metal cladding lubricants), which allow, under certain conditions, to realize the effect of selective transfer, and additives of other particles that increase upon contact of surfaces in the mixed lubrication mode proportion of solid lubricated areas. Areas of rational use of various antifriction alloys and journal materials are presented in Table. 2.

Table 2. Areas of rational use of antifriction alloys for plain bearings.

Alloys	Workingconditions			Recommended technological and design factors			
	p, MPa	**υ, m/s**	**t oils, °C**	**Thickness alloylayer, mm**	**Bearingfitaccuracy, mm**	**Neckhardness HB, MPa**	**Way of attaching the alloy to the body**
Babbitsofallbrands	1-5	2-5	50	3,0	Tenths	–	Mechanical (inslots)
	1-5	5-10	60	3,0	Same		Metallurgical (tinning)
Babbits:							

Б83, Б16, БН, БТ, Б6, БС1	5-10	5-10	75	3,0	hundredths	-	Same
БК2, СОС6-6, БС2, Б92	5-12	10	80	1,0	Same	-	Same
БК2, Б92	8-15	15	100	0,1-0,3	thousandths	–	Same
Zincapplied onsteel	15-25	15	100	1,0	Same	3000	Metallurgical (rollingorpouring)
Aluminum without soft component deposited on steel	15-25	15	100	0,5	Same	3000	Metallurgical (rolling)
Solid aluminum with soft phase	15-20	15	100	–	Same	2000	–
Lead bronze applied to steel	15-25	15	110	0,5	Same	4000	Metallurgical (pouringorsintering)
Aluminum with soft phase deposited on steel	20-30	20	120	0,5	Same	3000	Metallurgical (rollingorpouring)

Recommendations for the use of various metals are made taking into account technological and design factors. At the same time, indicators of compatibility of rubbing surfaces were taken into account. In some cases, bearings operate in friction mode without lubrication. This is dictated by the relevant design parameters of the units and operating conditions (vacuum, high heating level, etc.). Sometimes friction without lubrication is a consequence of an emergency state of the tribosystem that occurs with a sharp increase in load, cessation of lubrication, and for other reasons. In friction without lubrication, relatively stable operation is achieved by using anti-friction materials containing solid lubricants and soft structural components and having self-lubricating properties (for example, metal-fluoroplastic material, aluminum-tin alloy, etc.).

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