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The Essence of Mechanical Losses and Their Size, Processes of Friction, Lubrication and Wear in Engine Assembly

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Annotation: Parameters of the dependence of indicators of the technical condition of the engine and oil on the volume of oil added, clarifying and allowing to determine the engine resource and operating time before changing the oil. Parameters of the regime for maintaining the functional state of the lubrication system of forced engines in operation, differing in the frequency and volume of adding oil, which make it possible to exclude extreme lubrication modes.

Keywords: Lubricant, technical equipment, maintenance, technical condition diagnostics, vehicle maintenance, maintenance and repairs, internal combustion engine, friction, lubrication, wear processes in engine units

In the theory of internal combustion engines, mechanical losses are considered as the energy expended to overcome all types of resistance to the movement of parts, air and liquids. According to various estimates made for specific types of internal combustion engines, the proportion of mechanical losses related to the indicated power in the nominal operating mode of naturally aspirated autotractor diesel engines ranges from 15 to 25%. This suggests that about a quarter of the available gas energy in a piston engine is irretrievably lost to overcome friction [1].

The lubricant prevents direct contact of the surfaces, cools them and carries away the products of wear and oil oxidation. In addition, it interacts with metals and significantly changes the mechanical properties, wear resistance, and fatigue strength of surface layers [2].

In the friction contact zone, the strength of the lubricating layer depends on the load, sliding speed, temperature, mechanical properties of materials and surface condition, layer thickness and composition. These factors determine the types of friction, which can be divided into fluid, boundary, elastohydrodynamic and friction without lubricant. Such a division is arbitrary, since the parts of internal combustion engines operate in mixed friction modes, where various types of mechanical and corrosion-mechanical wear are realized.

More complex processes, depending on operating conditions, occur when parts of internal combustion engines wear out. Out of external factors, abrasive particles and temperature in the friction contact zone have the greatest influence on the wear intensity due to micro-seizure. Particularly unfavorable friction conditions in the engine cylinder occur when reversing in zones of minimum piston speeds, especially near the combustion chamber, where the temperature of the friction surfaces of the cylinder and rings reaches 350 ° C, the maximum pressure is 6-16 MPa, and the minimum thickness of the oil film, which is liquefied by the working mixture, burns out during the ignition period and is blown out from under the upper rings at the time of the compression stroke [3]. Therefore, near dead spots, a complete destruction of the oil film is always observed.

Metallic interaction and seizure in engine cylinders are facilitated by: thermal activation, temperature rise to the level of destruction of oil and adsorption films, temperature flashes at active centers at the moment of exit of dislocation steps.

The main types of wear of the cylinder-piston group are mechanical, fatigue, abrasive and corrosion-mechanical. The intensity of corrosion-mechanical wear is influenced by fuel combustion products, especially sulfur and vanadium compounds. This leads to a change in the mechanical properties of the surface layers of materials, their embrittlement, and separation of particles as a result of frictional interaction [3].

The source of abrasive particles is the air entering the combustion chamber to form a combustible mixture. The amount of abrasive particles entering the cylinder depends on the operating conditions and the degree of diesel forcing. It has been established that particles of 35 μm in size have the greatest influence on abrasive wear. In addition, wear products, consisting of hard metal particles, have an abrasive effect. They are able to migrate between rubbing surfaces and damage them. The products of fuel combustion (soot) also contribute to the wear of engine parts.

The work of the main and connecting rod bearings of the crankshaft is characterized by alternating load and differences in sliding speeds. The friction pair "shaft-bearing" operates under conditions of fluid friction. To ensure this mode, it is necessary to correctly calculate the thickness of the oil layer, taking into account deviations in the geometric shape and surface roughness. The calculation of the work of a plain bearing under liquid friction is carried out according to methods based on the elastic-hydrodynamic theory of lubrication [4,5]. The hydrodynamic lifting force of the oil layer depends on the sliding speed, oil viscosity, radial clearance, load and design parameters of the shaft and bearing. In real operating conditions, fluid friction occurs at a steady state of friction. When starting and stopping the engine or operating at low speeds, fluid friction becomes boundary.

The tribological characteristics of the contact are determined by the thickness of the lubricating oil layer and its viscosity [5,6]. In this case, sliding between molecular rows occurs in the oil layer, which is a distinctive factor in liquid friction.

Boundary friction is characterized by the interaction of solid bodies separated by a monolayer of lubricant. In this case, the sliding speed and specific loads are such that the lifting force of the hydrodynamic effect is negligibly small [6]. Boundary layers are formed on the surfaces of solids due to the adsorption and chemisorption of active oil molecules, as well as the adhesion of polarly active particles.

There are critical film thicknesses below which slip between the molecular rows of the lubricant does not occur. Such layers withstand large normal loads and acquire the properties of a quasi-elastic body [7,8].

Most units of mechanical systems operate under conditions of boundary lubrication, in which the metal contact of rubbing bodies is prevented by the formation of boundary lubricating layers of various origins on the friction surfaces. They are formed as a result of the interaction of the working surfaces activated by the friction process with the active components of the lubricant. The ability of a lubricant to form strong boundary layers of sufficient thickness in short periods of time largely determines the durability of heavily loaded units operating constantly or periodically in the boundary lubrication mode, as well as the antiwear properties of the lubricant itself [8].

The formation of protective adsorption, chemisorption and modified layers is explained by the adaptability of the tribosystem to external influences and is its protective function. The essence of this phenomenon lies in the fact that during its implementation, all interactions between rubbing bodies and the medium are localized in thin layers of secondary friction structures formed on the initial materials due to their structural rearrangement and interaction with the medium [8].

A review of the world experience in the application of tribological methods to reduce mechanical losses in internal combustion engines shows that the most promising areas for solving the problem are [9, 10]:

1) profiling of friction surfaces of lubricated parts of reciprocating motion;

2) improvement of antifriction and antiwear properties of structural and lubricant materials;

3) improvement of the computational technology for reducing the wear of internal combustion engines in operation by modifying friction and controlling oil aging and experimental evaluation of mechanical losses at the stage of engine design and refinement

Analyzing these areas, we note that the effectiveness of reducing mechanical losses in domestic mechanical engineering is still insufficient due to the separate, rather than integrated application of these areas and their corresponding methods. The profiling methodology does not take into account the most important condition for reducing mechanical energy losses - matching the parameters of the profile of parts with the nature of the kinematics, external load and lubrication of the assembly. When choosing materials, the concept of strength dominates over energy savings. Calculation and experimental methods require development in order to solve the problems of taking into account design parameters and material properties.

Thus, the proportion of mechanical losses referred to the indicator power at the nominal operating mode of gasoline automobile engines and naturally aspirated autotractor diesel engines is characterized by a large value (up to 25%) for domestic internal combustion engines and a lower value (15%) for their foreign counterparts.

It follows from the estimates that the fuel costs directly related to friction in specific terms range from 7 to

eleven %. Comparison of prototypes and analogues with certainty indicates that, other things being equal, the cause of high mechanical losses is, first of all, in the low level of design and manufacturing technology of parts of the cylinder-piston group and the crank mechanism; and, additionally, in the worst antifriction properties of lubricants [11].

The latter circumstance, in view of the appearance on the domestic market of imported motor engines and the gradual approach to them in terms of the quality of domestic products, is now, most likely, no longer a factor restraining the reduction of mechanical losses. Therefore, the high level of energy costs to overcome friction in reciprocating engines is mainly due to:

- errors in the design and technological support of the main parts;
- neglect of the tribological aspect of engine operation and, as a result, the lack of an approach to the design of friction parts as an energy-saving object;
- ignorance of the true level of mechanical losses of the designed structure, which, in turn, is associated with insufficient development and applicability of methods for calculating and experimentally controlling friction parameters in the main movable interfaces of internal combustion engines.

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