TRIBOLOGICAL PROPERTIES OF PISTON-CYLINDER SET IN INTERNAL COMBUSTION ENGINES

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Abstract:
This paper presents a wear process analysis of piston-cylinder set in internal combustion engines.Piston mechanism is a very important factor in the proper lubrication of the engine, but also a potential cause of increased consumption of oil. There are very important kinematic - tribological properties of piston mechanisms in this regard. From the point of reliability and functionality, critical parts of this circuit are the piston rings. Wear is most pronounced in the first piston ring, since it is exposed to the highest pressure and temperature, as well as the direct impact of fuel and combustion products. The intensity of wear of piston - cylinder set depends on many factors, but the most influential ones are: construction, materials used for the production of the parts of this assembly, production technology and conditions of use.

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1. INTRODUCTION

A vehicle is an extremely complex technical system, composed of many interconnected parts many of them rely on the interaction of surfaces in the work [1]. There are a number of wear components, such as bearings, assemblies of engines, gearboxes, couplings, gears up towel, rubber, electrical contacts, etc.

Internal combustion engines belong to the group of heat engines that generate thermal energy by burning fuel into mechanical work. On its construction, the engine is very complex. It consists of circuits which are in mutual relative motion, whereby the contact occurring in their different complex physical-chemical phenomena that depends on the material and its structure, micro and macro-contact surfaces, the geometry of the components, conditions, trends, ways of lubrication, the presence of other materials on and other areas [2]. Engine blocks were previously made with cast iron, and in recent years are designed and manufactured in aluminium and its alloys, resulting in significant weight savings [3-4]. In addition, parts of piston engines are exposed to high loads, high temperatures and move at high speeds.

In mutual relative motion engine parts slip over each other in what are the places of their contact friction occurs. Friction increases with increasing temperature and load so that the parts causes wear. Wear can manifest itself in the loss of material from the contact surfaces which may lead to changes in parts dimensions, and thus to a decrease in work efficiency and engine failure [5-6]. Wear and friction properties depend on the frequency of creation and change type of lubrication that change during engine operation, as well as the formation of molecular lubricant film.

The process of wear greatly affects the reliability of the component parts of the engine. This fact points to the need to establish indicators of working capacity engines that depend on the degree of wear of their parts and determination of their allowable size [7].

2. FRICTION AND CONDITIONS OF LUBRICATION IN INTERNAL COMBUSTION ENGINES

Friction between engine parts that are in motion absorbs a substantial part of the developed engine power. In addition, the heat developed by friction can jeopardize the functionality of the most responsible engine parts.

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Depending on the mode and conditions of lubrication, three types of friction can occur in the engine [8]:

- dry friction,
- semi-dry or semi-liquid friction
- liquid friction.

Dry friction occurs in conditions without lubrication where the direct contact between the metal surfaces is made. Since the sliding surfaces are not ideally smooth touch is achieved at the tops of bumps, and because of the shear that occurs at the point of contact, develops heat, which leads to the formation of so-called micro-welds. Dry friction is extremely undesirable, and the engine can occur only for short periods and during the start.

Semi-liquid or semi-dry friction occurs in the boundary lubrication. Then contact patch delivers more or less by their irregularities, while the lubricant located in the recesses prominence. While the lubricant layer is less than the height of the surface roughness of sliding friction occurs limit. With increasing temperature, which develops due to friction, diminishes the effectiveness of border oil layer, that tends to be the engine running in these conditions as short period of time.

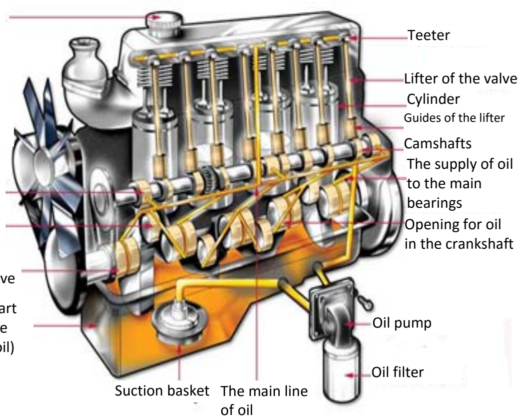

Fig. 1. Engine lubrication system, [9]

Liquid friction is friction vision pursued in the system of engine lubrication. Metal surfaces are then completely separated by a layer of a liquid lubricant so that the load is transferred from one surface to the other through the film of the lubricant. For realization of the liquid friction, it is necessary to realize the lubricant layer so that the thickness is greater than the roughness of sliding surfaces, i.e. hydrodynamic lubricating is achieved by the input wedge layer of lubricant between surfaces.

Without proper lubrication of the sliding surface of the motor a proper engine operation cannot be imagined. This requirement is obligatory for the lubrication system (Figure 1) [9].

Engine lubrication reduces friction, limits the wear and improves engine cooling.

3. ANALYSIS OF THE WEAR PROCESS OF PISTON - CYLINDER SET

Observed from the tribology perspective, friction in the piston part takes place in a system consisting of cylinder liners, piston rings, piston as the carrier of piston rings and structural clearance between the piston and liner as well as the environment in which there is lubricating oil (Figure 2).

Critical parts of this circuit are piston rings, because the conditions of their work are extremely unfavorable. They are exposed to the heat, the functioning and operation of corrosion which causes the combustion products of high pressure and at the same time insufficient lubrication of the contact surfaces. For these reasons, the dominant mechanism of wear that occurs in conjunction piston rings - cylinder eat corrosive - mechanical wear.

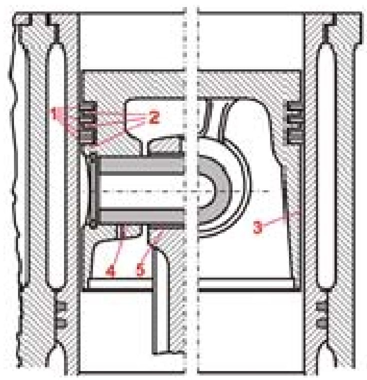

Fig. 2. Cross section of the piston mechanism with the IC engine showing the main tribological pairs, [10]

The piston rings are the most wear a working surface that is in contact with the cylinder wall, especially in the first compression piston ring. Wear properties are consequences of the increase in the gap between the ring and the side surfaces of the groove of the piston, as well as reducing their elasticity [11].

On the other hand, the maximum cylinder liner wear occurs around the area where it changes direction of movement, namely in its upper part (Figure 3). Wear characteristics cylinders points to uneven wear height - above the dashed line represents the position of the upper edge of the piston ring when the piston is at TDC, where the most intense wear of the cylinder [12].

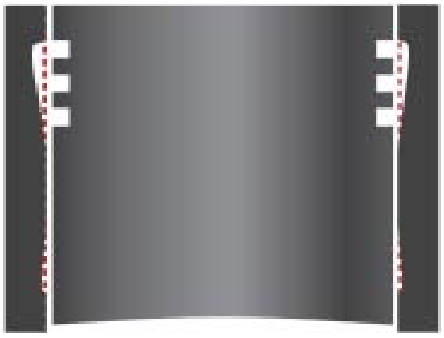

Fig. 3. Characteristic of the wear cylinders, [12]

The wear of the piston is much lower than the wear of piston rings and cylinder, a critical part of the piston grooves for piston rings. The intensity of wear of the piston depends primarily on the gap between the piston and the cylinder casing, oil film thickness, working temperature, working conditions, as well as the properties of the material contact surfaces [13-15].

Fig. 4. Wear the mantle clip, [15]

Bearing in mind that the piston is made of aluminum alloy that expands due to temperature approximately twice the cylinder of cast iron, and that the piston operating temperature is significantly higher than the temperature of the cylinder, it may cause a decrease in the working gap. With the reduction of gaps in the wall of the pressure, piston cylinder gradually increases, causing wear and boards exposed mantle surface of the piston (Figure 4). In doing so, the heat caused by friction, raises the temperature of the surface which heats the oil film that loses its lubricating function.

Abrasion due to the lack of oil can occur when the gap is satisfactory. The oily film, which separates from the wall of the piston cylinder during warm loses its effectiveness, often only locally. In these areas there is contact between the piston and ungreased cylinder which results in rapid wear of the surface.

The wear of the pin holes occurs as a primary impairment but can also be secondary to the wear of the mantle [16]. Since in the tray supports the pin does not bring oil under pressure, more lubricated oil spray, tear always occurs due to dry friction, with significantly cracked surface and welding materials (Figure 5). In the case of the primary tear holes in the floating pins, pin movement of the piston rod is limited by the lack of a gap and jams due to improper positioning of the piston rod so that the pin is forced to rotate only in the holes in the piston. The result is overheating caused by interruption of lubrication and dry friction and wear are then inevitable.

Fig. 5. Wear in the pin hole, [16]

Abrasive wear of piston-cylinder assembly cause mainly particles of mineral origin that penetrate into the engine different paths. In addition to abrasive particles due to the side, in the oil build up and wear debris, usually reinforced particles and oxides of metals having a higher hardness than the initial hardness of the active surface. When the dimensions of the abrasive particles become larger than the thickness of the lubricating layer, the destruction of the oil film occurs and the coupling surface becomes active as well in dry friction (Figure 6). Possible causes are scratching of the piston and rings as well as the cylinder wear as the result of abrasive particles in oil.

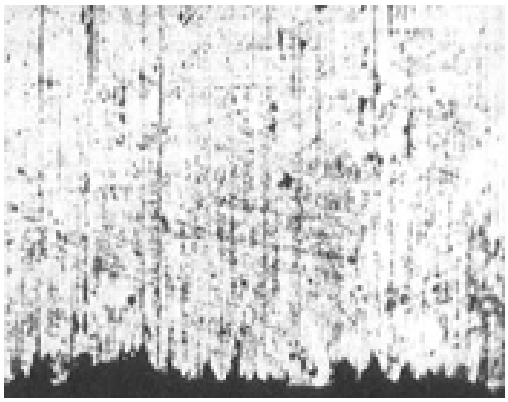

Fig. 6. Wear due to contaminants, [16]

When it comes to determining the wear of individual components of the piston assembly, the most systematized procedure is lengthy testing in laboratory conditions at precisely defined stages [13]. The intensity of wear in such conditions is a very important parameter in determining the resulting effects and correlations with the wear of the scheduled period of the repaired components, piston assembly. A very important parameter in such studies is the selection of appropriate engine oil and follow-up of its characteristics during the testing process.

In order to improve the tribological properties and thus reduce friction and wear elements of the piston assembly thin coating on the base metal and graphite is used. For this purpose, a large number of experimental studies were conducted which used different types of coatings, whereby bringing concrete proposals for preventing wear [13,14,17,18,19,20].

Aluminum alloys have good resistance to wear and do not require additional surface protection in the event of assembly cylinder of gray cast iron. However, surface protection contact surface of the piston assembly can provide additional security and to the creation of metallic coatings. Depending on the function to be achieved coatings, mainly used coatings that protect surfaces, especially of thermal loads and coatings intended to improve sliding properties. In addition, new solutions to the piston assembly triboelastic cartridges those characteristics have been improved by applying thin coatings also give very good results in terms of reducing the coefficient of friction and thus wear.

The wear of pistons, piston rings and cylinder engine lead to reduced engine power. In this part of the working mixture passes into the sump, which leads to increased fuel consumption and mixing of oil and fuel and thus to poor lubrication of the engine. In addition, the penetration of oil into the combustion space occurs, leading to the increased oil consumption and the creation of soot which adversely affects the operation of the engine.

4. CONCLUSION

The largest part of the mechanical losses in the engine combustion occurs due to the unwinding of tribomechanical process in the piston group, around 48-51%. Therefore, special attention is paid to the study of the mechanism of friction, which is otherwise very complex.

The intensity of friction piston assembly affects a large number of parameters, where the most important ones are: specific oil pressure and compression piston rings on the wall of the cylinder, the engine speed, the roughness of the working surface, the distance running surface, the pressure and the temperature in the work area, load on the engine in service, quality oil cooling system, the quality of materials and other parameters. The influence of some parameters on elevated consumption of fuel and oil were determined and they have the primary importance on the intensity of the friction, while the influence of other are unexplored in practice and they have a secondary character.

New solutions to this complex triboelastic cartridges allow: a lower coefficient of friction to the 30-50% and therefore less wear, better flow of lubricants for easier engine start, lower sensitivity of the deposits and other types of pollution and easy maintenance. The overhaul of piston groups reduced to the exchange of rings and liners, which eyelids increases and applying the appropriate coating. Thats elastic sliding properties triboelastic cartridges provide guidance through the piston cylinder, which reduces noise, impact and mechanical loading assembly of the piston - cylinder liner. Good tribological properties of the surface will affect the cylinder liners longer life and easier maintenance of the motor.

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