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REGULARITIES OF THE MECHANISM OF VARNISH FORMATION ON THE SURFACE OF PARTS OF INTERNAL COMBUSTION ENGINES

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Annotation

Varnish deposits, like carbon deposits, worsen the cooling of parts. The varnish contributes to the burning of piston rings. The combustion of the rings promotes the penetration of oil into the combustion chamber and increases its consumption. Burnt rings reduce engine compression, this leads to a breakthrough of gases into the crankcase and a decrease in engine power, and also causes excessive friction, increased wear and tear of the cylinder mirror, ring breakage, and sometimes jamming of the piston in the cylinder.

With an increase in the duration of heating the oil at a constant temperature, the formation of varnish increases until the oil completely turns into varnish.

Keywords: engine oils, deposits, viscosity, loads in the friction unit, oil film, carbon deposits.

Introduction

Varnish deposits are thin varnish-like films of light to dark color formed on the side surface of pistons in the area of piston rings, on the skirt, inner walls of pistons and in the upper heads of connecting rods. Lacquer deposits include the formation of dense products of oxidative transformations of oils on hot metal surfaces. Despite the fact that the thickness of the varnish deposits is relatively small (50-200 microns), they significantly complicate the operation of the engines.

The carbon-forming ability of oil is understood as its tendency to form carbon deposits in engines. Carbon deposits are products of deep oxidation of oil hydrocarbons in the form of solid deposits on the walls of the combustion chamber, the bottom of the piston, valves, injectors, etc. Fuel also takes part in the formation of carbon deposits. According to the structure, carbon deposits can be monolithic, plastic and loose. The chemical composition of carbon deposits is extremely unstable, it depends not only on the quality of oil and fuel, but also on the operating mode of the engine, dustiness of the air, etc. The main part of carbon deposits are carbenes and carboides (50-70%), asphaltenes and oxy acids account for 3.6%, resins and oils 15-40% and ash 1-10%.

The complex mechanism of carbon formation can be schematically represented in the following form. Oil trapped in the combustion chamber as a result of the pumping action of the piston rings spreads over the bottom and hot walls of the combustion chamber. At the same time, part of it evaporates and burns together with the fuel, and part remains on the surface in the form of a layer of thick resinous mass.

Varnish deposits, like carbon deposits, worsen the cooling of parts. The varnish contributes to the burning of piston rings. The combustion of piston rings, their jamming in the grooves of the piston, occurs due to the fact that the grooves are filled initially with sticky oxidation products, which then turn into varnish and firmly attach the ring to the walls of the groove.

The combustion of the rings promotes the penetration of oil into the combustion chamber and increases its consumption. Burnt rings reduce engine compression, this leads to a breakthrough of gases into the crankcase and a decrease in engine power, and also causes excessive friction, increased wear and tear of the cylinder mirror, ring breakage, and sometimes jamming of the piston in the cylinder.

The lacquer film on the parts acts like a layer of thermal insulation, which leads to an increase in the temperature of the parts and further stimulation of varnish formation. The complex mechanism of varnish formation generally consists of 2 processes of oxidation of a thin layer of oil directly on the surface of the heated part and coagulation on the surface of the part of solid oil oxidation products formed in other zones, as well as oxidation products and incomplete combustion of fuel.

In some cases, varnish formation can occur oxidative, when there are no carbonaceous particles in the lubricating oil, or coagulation, when the lubricating oil is saturated to a certain limit with carbonaceous particles, and the temperature of the parts is relatively low (100-120^{o}C), at which oxidative processes cannot develop intensively (Fig. 1).

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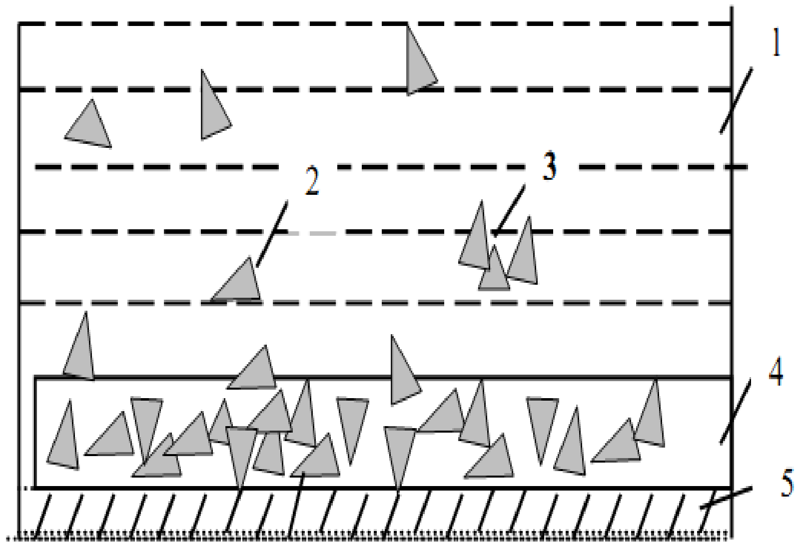

Fig.1. The process of varnishing on a hot metal surface:
1 - lubricating oil; 2, 3- particles of oxidation products; 4 - lacquer film; 5 - metal.

The temperature, the oxidation time, the quantity and quality of the supplied oil (the thickness of the oil layer), and the catalytic effect of the metal affect the varnish formation most strongly. Temperature is one of the decisive factors of varnish formation.

When a thin layer of oil is oxidized on a metal surface in a static state, an increase in temperature increases the rate of varnish formation. The amount of the resulting varnish also increases, and then, after reaching the maximum, it begins to decrease. The reason for the decrease in the amount of varnish is cracking and carbonation of the film, which increases the yield of volatile substances. With an increase in temperature, the amount of oxidation products in the oil volume increases and the coagulation of carbonaceous particles is facilitated, which also contributes to varnish formation.

With an increase in the amount of oil supplied to the rubbing parts, the varnish formation decreases, since the temperature of the oil layer decreases and the oxidation process slows down. The more the oil is heated at a constant temperature, the more varnish is formed.

The thickness of the oil film affects both the rate of formation and the amount of varnish formed. With a decrease in the thickness of the oil layer, the processes of varnish formation begin even at lower temperatures.

The degree of maximum conversion of oil into varnish at a constant heating duration is a function of temperature and does not depend on the thickness of the oil layer within 10-200 microns. In contrast to the degree of varnish formation, the

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amount of varnish formed per surface unit is directly dependent on the thickness of the oil layer. Figure 2 shows the amount of varnish per 1m metal surface (grams) depending on the thickness of the oil layer (mm).

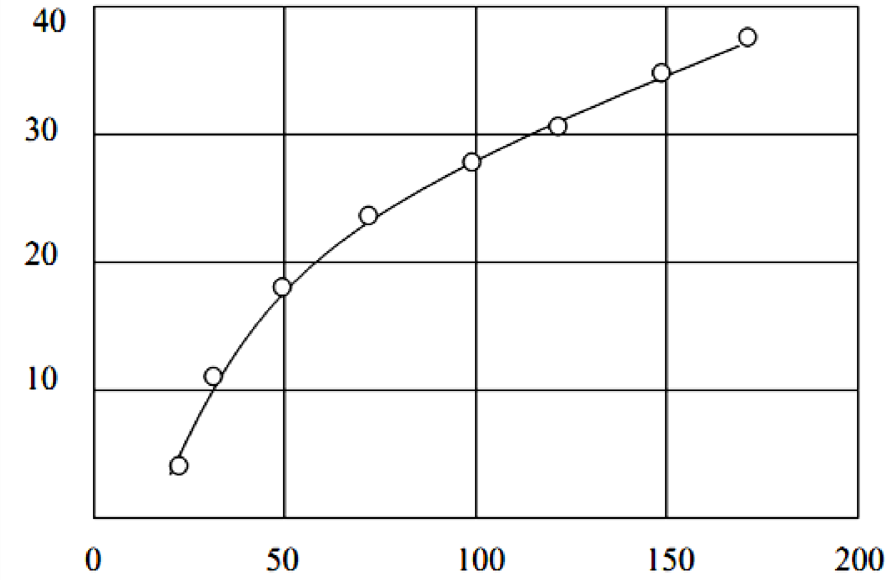

Fig. 2. The amount of varnish formed on the metal surface

The greater the thickness of the oil layer within 10-200 microns, the more varnish can be formed by weight per unit surface. The catalytic effect of metals has an important effect on the oxidation of oil in a thin layer. The catalytic efficiency of metals varies depending on temperature conditions. The difference in the catalytic effect of metals on varnish formation is most significant in the temperature range of 250-280°C. At higher temperatures (300°C), it begins to smooth out.

In accordance with the mechanism of varnish formation, the following properties of the oil are distinguished that affect the varnish formation: thermo-oxidative stability and detergent properties.

Thermal oxidative stability refers to the oil's resistance to oxidation in a thin layer at elevated temperature. The basis of the method for assessing the thermal-oxidative stability is the determination of the strength of the lacquer film. For example, the time (in minutes) is measured during which a lacquer film is formed on a metal disk at a temperature of 250°C during the oxidation of 0.05 g of oil, which holds the metal ring when detached with a force of 1 kg. The slower the oil is oxidized, the longer it takes to form a film of a given strength.

Summarizing the above, we can draw the following conclusion:

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1. The process of oxidation of a thin layer of oil is accompanied by intensive evaporation of a significant part of the oil. The final product of oxidation is the products of oxidative polymerization deposited on the metal surface in the form of lacquer deposits.
2. The rate of varnish formation increases with an increase in the heating temperature and with a decrease in the oil layer.
3. With a constant duration of oil heating, there is a temperature of maximum varnish formation.
4. The largest amount of varnish is formed from oil at the lowest temperature, at which the process of varnish formation is only going on, and with the longest heating.
5. With an increase in the duration of heating the oil at a constant temperature, the formation of varnish increases until the oil completely turns into varnish.

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