Influence of the antioxidant properties of lubricants on the wear of agricultural machinery parts

Z X Alimova¹, N A Kholikova², S O Kholova³, K G Karimova⁴

¹Tashkent State Transport University, St. Odilxojayev 1, Tashkent, Uzbekistan
²Tashkent institute of irrigation and agricultural mechanization engineers, St.Kari Niyaziy 39, Tashkent, Uzbekistan
³Tashkent institute of irrigation and agricultural mechanization engineers, St.Kari Niyaziy 39, Tashkent, Uzbekistan
⁴Jizzakh Polytechnic Institute, St.I.Kaimov 4, Jizzakh, Uzbekistan

E-mail: zeboalimova7841@mail.ru

Abstract. The article analyzes the influence of the oxidation process of motor oils on the operation of the engine. The main reason leading to the formation of high-temperature deposits in engines is oxidation processes occurring in the volume of the oil and on the metal surface. These deposits negatively affect the reliability, efficiency, and durability of the engine. Among the numerous properties on which the assessment of the quality of lubricants based on antioxidant properties are important. Therefore, we suggested introducing detergent additives into the engine oil. The action of such additives gives the ability to loosen, wash away deposits from the surface of parts, and transfer insoluble substances into suspension. The results of laboratory studies of samples of industrial oils and samples with the addition of new additives and recommendations for their use are presented.

1. Introduction

Every engine, even of the same brand, works in different conditions and wears out differently. Modern internal combustion engines require high quality lubricating oils to ensure optimum operating conditions.

The reliability and durability of the car depend on the quality of the lubricants used. In this regard, all lubricants without exception must meet the quality requirements of the standard.

The highest quality oils will not ensure the operation of mechanisms without wear if they contain at least a small amount of mechanical impurities.

The amount of mechanical impurities is strictly limited and for engines, oils should be no more than 0.015%. Studies of the contamination of lubricating oils in the operating conditions of machinery show that in hot climates and high dustiness of the air, engine oils are intensively contaminated with mechanical impurities, water, fuel and organic products, which leads to premature aging of the oil.

Oil oxidation occurs either in its entire volume or in a thick layer, or in a thin layer when the oil is pumping through the cylinder-piston friction units.

In the latter case, the hydrocarbons of the oil are in particularly difficult conditions of temperature and contact with atmospheric oxygen and metal.
Oxidation of oil in the stream occurs during engine operation when the lubricating oil is continuously circulating and engine parts are constantly lubricating with new portions [1].

2. **Analyze of research**

During the operation of internal combustion engines, their units and parts are contamination with various deposits. The process of formation of deposits is associated with thermo-oxidative transformations of products of incomplete combustion of fuel and oil components. The main reason leading to the formation of high-temperature deposits in engines are oxidation processes occurring in the volume of the oil and on the metal surface.

Oxidation products of hydrocarbons (resins, organic acids), present in the oil in a dissolved state, increase the viscosity and acid number, and asphalting compounds, which are the basis for the formation of varnishes and especially dangerous sticky deposits, contribute to the occurrence and burning of piston rings.

The products of deep oxidative polymerization, differing in high-temperature zones and returning to the crankcase, like other precipitated deposits, continue to have a negative effect on the oil. These deposits have a negative effect on the reliability, efficiency and durability of the engine.

Increased air pressure accelerates the oxidation process, as the process of mutual diffusion of oil with atmospheric air is enhance. In this case, the temperature has a decisive influence on the oxidation process.

The purpose of this work is to study the process of oxidation of engine oil during engine operation and suggests ways to improve antioxidant properties.

The primary products of hydrocarbon oxidation are hydroperoxides. The process develops according to a radical-chain mechanism, and, thus, it considered autocatalytic. Hydroperoxides further decomposed and converted into other oxygen-containing compounds. More and more oil hydrocarbons are involved in the oxidation reaction. As a result, depending on the conditions and chemical composition of the oil, the following products can accumulate in the oxidized oil: low and high molecular weight acids, hydroxy acids, alcohols, aldehydes, ketones, phenols, lactones and other substances [2].

Oxyacids and products from condensation: lactides, estolides and others are also very poorly soluble in hydrocarbons. Therefore, they either form carbonaceous deposits, such as carbon deposits or deposited on various parts of the piston group of the engine in the form of a thin and very durable layer, resembling in appearance a varnish coating. On less hot parts, hydroxy acids give sticky deposits. The formation of varnish films is the result of the oxidation of oils in a thin layer. Varnish deposits cause the piston rings to burn and overheat the parts on which the deposits have formed.

All this leads to a decrease in engine power, its quickest wear and an increase in oil consumption.

The catalytic action of metals has an important effect on oil oxidation. The catalytic action of metals ceases when it covered with a protective film created by oxidation products [3].
As a result of oxidation, the chemical composition of the lubricant and its physicochemical properties change. All this affects the ability of the lubricant to perform its intended functions, limits its service life, and worsens the technical condition of engines. Oils that are not resistant to oxidation tend to sludge more quickly and to a greater extent than stable oils. Oils with special additives are less prone to sludge formation than pure oils because additives allow better retention of insoluble impurities and better resistance to oxidation.

Phenols and amines used as antioxidants, and organic compounds of sulfur and phosphorus used as metal deactivators. Antioxidant additives also include substances that reduce the activity of the catalytic action of metals, their oxides and salts on the oxidation process - metal passivators. However, the existing antioxidants additives can not to the required extent inhibit the oxidation of oils in the medium-temperature zone and completely prevent the formation of varnish-forming substances in it [5].

Before giving recommendations on the use of any additives, it is necessary to study the mechanism of their action, without the knowledge of which their effective use is impossible.

The research shows that substances containing both sulfur and nitrogen are very effective against oxidizing properties. Tests of several dozen of these compounds as oil additives have shown that they are very effective not only for fresh oils, but also for used and recovered oils.

As antioxidant additives, we used an additive calcium alkylaryl sulfonate (CK-3) - calcium salts of aromatic sulfonic acids [2]:

![Chemical structure of calcium alkylaryl sulfonate (CK-3)](image)

These additives have the ability to improve the quality characteristics of oils. In the oxidation of mixtures of hydrocarbons, aromatic hydrocarbons have an inhibitory effect on the oxidation of naphthenes. This is because the oxidation products of aromatic hydrocarbons, phenols, have antioxidant functions.

Thus, the best group composition of the oil from the point of view of its chemical stability corresponds to a mixture of low-cycle naphthenic, aromatic and hybrid hydrocarbons with long saturated side chains [4].

This additive protects oils from oxidation by a chain-breaking action by reducing the number of radicals generated. The effect of such additives based on their ability to loosen, wash away deposits from the surface of parts, transfer insoluble substances into a suspension, and keeps these particles in this state without coarsening.

The advantage of this additive over other additives is that it is quite effective at relatively low temperatures (up to 150-175 °C) and is stable up to 300 °C. To achieve the desired effect, it is required to apply it in quantities of 5-10%.

This antioxidant protects the oil from oxidation by acting to terminate the reaction chain by reducing the amount of radicals formed [2].

This inhibitor (InH) easily gives up its hydrogen to the radicals of the main oxidizing substance, thus transferring them to an inactive state and replacing them with In- radicals, which, due to their relatively low activity, are unable to regenerate radicals and continue the chain:

\[
R^\cdot + \text{InH} \rightleftharpoons RH + \text{In}^- \\
\text{ROO}^- + \text{InH} \rightleftharpoons \text{ROOH} + \text{In}^-
\]
The action of such additives will be mainly aimed at preventing the formation of the primary oxidation products - peroxides.

Based on this, we analyzed M-10V2 motor oils and SK-3 sulfonate additive. From literary sources, it is known that antioxidant additives introduced into oils up to 15%.

3. Method of research
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![Physicochemical indicators of engine oil for various concentrations of additives](image)

4. Conclusion
According to the results of laboratory studies, when the additive introduced into engine oil, they gave a positive result. From the results of the analysis, we have selected the content of additives SK-3 9%, which shows the optimal value of viscosity and base number. With a further increase in concentration, the viscosity increases strongly, which can lead to increased frictional losses. With an increase in viscosity, the thickness and resistance to mechanical stress of the oil layer between the rubbing surfaces increases.

The reserve of neutralizing properties that characterizes engine oil, called the base number, can vary from 5-10 mgKOH / g. The oxidation products of hydrocarbons present in the oil in a dissolved state contribute to the reduction of the base number. At the same time, acidic products accumulate in the oil, which increases the corrosive wear of parts. All this can lead to contamination of the parts of internal combustion engines with various varnish deposits. In our example, the base number increased from 4.8 to 6; and the flash point rose to 224°C, indicating the effectiveness of the additive added. This means that when using such an additive, the service life of the engine oil will increase.

Based on this analysis, it was found that the synthesized additive has a high detergency and can be used to effectively reduce the formation of varnish-forming substances arising on pistons and related parts.
According to the results of laboratory tests, when the additive introduced into M-10B\textsubscript{2} engine oil, the physicochemical indicators gave a positive result in comparison with M10B\textsubscript{2} oils. TBN increased from 5.0 to 6; and the flash point rose to 224\degree C, indicating the effectiveness of the additive added. This means that when using such an additive, the service life of the engine oil will increase.

Based on the results of the analysis, we selected the additive content of 9%, which shows the optimal viscosity and base number. With a further increase in concentration, the viscosity increases strongly, which can lead to increased frictional losses. With an increase in viscosity, the thickness and resistance to mechanical stress of the oil layer between the rubbing surfaces increases.

The studies show that the addition of an additive reduces the process of piston ring wear by 3-4\%, as well as an increase in efficiency by 1\%, which leads to an increase in engine power by about 4\%.

In the future, these oils can be admitted to the next stage - to operational tests on special equipment.

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