Improvement of properties of oils used in hydraulic systems of road-construction equipment

Z Alimova¹, N Kholikova¹ and S Kholova

Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

zeboalimova7841@mail.ru

Abstract. This article proposes ways to improve the operational properties of hydraulic oils used in road construction equipment. Hydraulic oils with additives in the form of metal dithiophosphates or orthophosphoric esters can provide reduced wear of hydraulic elements. We research samples of industrial oils MG – 30, and samples with the addition of zinc dithiophosphate additives DC – 40. The antiwear effect of such compounds occurs due to the adsorption of the metal surface with the formation of sufficiently strong compounds with the metal. In the presence of oxygen, the reactivity of sulfur compounds with respect to the metal decreases, but an increase in the antiwear properties of the compounds is observed mainly under moderate friction conditions.

The results of laboratory studies of MG-30 hydraulic oils with an additive based on zinc dithiophosphate DC – 7 and recommendations for their use are presented.

1. Introduction

Models of hydraulic systems used in road construction equipment are characterized by low weight, increased operating pressures and temperatures, reduced gaps between the working elements.

Along with the modernization of hydraulic drives, the requirements for hydraulic oils are being tightened: they must have a wide range of operating temperatures, maintain their performance for as long as possible and comply with strict environmental standards. Improving hydraulic drives entails a change in the composition and quality of hydraulic oils.

During operation in hydraulic systems, the oil is heated and intensively mixed with air. The main conditions in which oil is used in hydraulic systems are characterized by wide fluctuations in the temperature of the ambient air, the transmission of large forces, and the effect of high specific loads in the pumps, dustiness, and humidity of the surrounding air.

The hydraulic drive does not work without a special liquid medium, therefore its presence in the hydraulic system is mandatory. The main task of hydraulic fluids is to transfer mechanical energy to the place of use.

Hydraulic oil performs the function of a working fluid (liquid medium) in the vast majority of hydraulic systems in industry and transport, in brake and shock absorbers. Most hydraulic fluids are made from base oils obtained from petroleum fractions by extraction and hydrocatalytic purification.

Under the influence of high temperatures, atmospheric oxygen, and condensing water, the catalytic effect of metals, the chemical composition of oils and their operational properties sharply change. This
leads to an increase in the viscosity of the oil and to the accumulation of oxidation products in it. As a result, depending on the conditions and chemical composition of the oil, low molecular and high molecular acids, aldehydes, ketones, phenols, lactones can accumulate in oxidized oil.

\[
\begin{align*}
 & \text{R-CHOH} + \text{OHCH-R} \\
 & \text{COOH} + \text{COOH} \\
 & \Rightarrow 2\text{H}_2\text{O} + \text{R-CH-O-CO} \\
 & \text{CO-O-CH-R} \\
 & \Rightarrow \text{H}_2\text{O} + \text{R-CH-OH} \\
 & \text{CO-O-CH-R} \\
 & \text{COOH}
\end{align*}
\]

High molecular acids in oxygen and water react with these conditions with ferrous oxide hydrate:

\[
\text{Fe (OH)}_2 + 2\text{RCOOH (RCOOH)} \rightarrow 2\text{Fe} + 2\text{H}_2\text{O}
\]

Salts of higher acid are poorly soluble in oils, precipitate, and in the form of slag on droplet-forming media and in the circulating oil system.

All this leads to an increase in energy costs for the drive of the hydraulic system. The resulting hydroxy acids give rise to esters and unsaturated acids. Additive according to studies, 70% of hydraulic failures occur due to the condition of the oil. Of these: 40% are directly related to operational quality oils, 60% are related to the purity of the oil.

2. Methods

This article proposes ways to improve the operational properties of hydraulic oils used for road construction equipment. If the oil does not withstand high temperatures, then it begins to oxidize, which leads to corrosion and wear. To prevent oxidation of the oil and reduce deposits on hydraulic transmission parts, antioxidant and detergent additives are added to the oils.

A prerequisite for the long-term operation of the oil is the reliable protection of the units from dust and moisture. Corrosion protection by a layer of lubricant located on the metal surface consists of its simple physical isolation from corrosion aggressors and the ability of the active components of the lubricant or corrosion inhibitors to form water-resistant adsorption or chemical film on the metal surface.

Of the substances containing both sulfur and nitrogen in the molecule and having very effective anti-oxidizing properties, a large group of sulfonamide compounds should be noted. Testing several dozen of these compounds as additives to oils has shown that they are very effective not only in fresh oils but also in used and regenerated ones. Particularly effective were sodium o-sulfanyaminobenzoate (sulfanthrol) and 2-p-amino-benzene-sulfamidopyridine (sulfidine):
These additives are also effective in cases where p-hydroxydiphenylamine is practically ineffective or inactive. The disadvantage of sulfanilamide compounds as additives is their poor solubility in oils.

Additives with several active elements are also introduced into the oils: S-Cl, S-P, Cl-P. In this case, the action of one active element when changing friction conditions is supplemented by the action of another. In complex sulfur-chlorine additives, sulfide films prevent scuffing, while chloride films, due to their elasticity, reduce wear and energy consumption to overcome friction.

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

Hydraulic oils with additives in the form of metal dithiophosphates or dithiophosphoric esters used in road-building machinery provide reduced wear of hydraulic elements.

Phosphorus-containing additives have a higher resistance to all types of oxidation compared to other additives. They have an incomparably greater chemical and thermal stability and therefore can come into contact with aggressive environments under conditions of hot temperature.

This article proposes ways to improve the physicochemical properties of hydraulic oils through the use of additives.

We studied samples of industrial oils MG-30 with the addition of zinc dithiophosphate additives DC-7.

Hydrocarbon radicals of such additives contain from three to eight-ten carbon atoms

$$(\text{RO})_2 P (S) S \text{Zn} S (S) P (\text{OR})_2$$

The characteristic properties of phosphorus-containing additives are their ability to reduce surface wear at moderate loads and to ensure high smoothness of the friction surfaces. The presence of a
phosphorus atom in the composition of zinc dithiophosphate increases the antiwear properties of lubricants. The antioxidant properties of zinc dithiophosphate are determined by the presence of thionic sulfur atoms in their molecule.

The peculiarity of zinc dithiophosphate is that these compounds, as well as the products of their thermal transformations, interact with the products of oxidation of hydrocarbons, which leads to the formation of new substances with antioxidant properties.

For this, the main indicators of the MG-30 base oil were determined according to State standard 305-2013 in the laboratory. Then, preliminary experiments were conducted to determine the effectiveness of the additives.

For better solubility, the additive was introduced into oil heated to 120 °C. To achieve the desired effect, it was required to apply it in amounts of 0.5-2%.

As the object of study was selected: hydraulic oil - MG-30 with different contents (0.5 ÷ 2.0%) of additives DC-7.

The mechanism of action of zinc dithiophosphate is associated with their thermal decomposition and the formation of a polymer film on the friction surface. The adhesion force between the oil molecules and the material of the lubricated surface exceeds the mutual adhesion force of the oil molecules, as a result of which a strong layer of lubricant forms on the metal surface.

At high temperatures in the zinc-sulfur-air system, the main reactions are between the solid phase and the environment. In the process of further decomposition, O-S-S is formed, the interaction of which with decomposition products leads to the formation of disulfide. The effectiveness of this action is characterized by the formation of metal sulfides and disulfides. This model involves the adsorption of a metal surface and the subsequent dissociation of molecules along S-S bonds with the formation of sufficiently strong compounds with the metal. The decomposition of zinc dithiophosphate molecules along the P-S-Zn bond is also possible. In the process of further decomposition, O, S, S-tri-n-alkyl trithiophosphate is formed, the interaction of which with decomposition products leads to the formation of disulfide. The formation of such complexes facilitates the effect of oxygen at the point of attachment of hydrocarbon radicals to sulfur.

The decomposition of dithiophosphate can occur both by radical and by ionic mechanism:

\[
\begin{align*}
\text{High molecular acids in oxygen and water react with these} & \quad \text{conditions with ferrous oxide hydrate:} \\
\text{Fe (OH)}_2 + 2R\text{COOH (RCOOH)2Fe + 2H}_2\text{O} & \quad \text{Salts of higher acid are poorly soluble in oils, precipitate, and in the form of slag on droplet-forming media and in the circulating oil system.}
\end{align*}
\]

The presence of such a layer eliminates the possibility of dry friction, and since the coefficient of friction between the layers of liquid lubricant is several tens of times lower than the coefficient of dry friction, the energy costs of overcoming the friction forces when using such oil are significantly reduced.
The figure shows the changes in the physicochemical parameters of the tested oil depending on the percentage concentration of DC-7.

According to studies, 70% of hydraulic failures occur due to the condition of the oil. Of these: 40% are directly related to the performance of the oil, 60% are related to the purity of the oil. This article proposes methods for improving the operational properties of hydraulic oils used for agricultural machinery. Hydraulic oils with additives in the form of metal dithiophosphates or orthophosphoric esters used in road-building machinery provide reduced wear of hydraulic elements. The presence of such a layer eliminates the possibility of dry friction, and since the coefficient of friction between the layers of liquid lubricant is several tens of times lower than the coefficient of dry friction, the energy costs of overcoming the friction forces when using such oil are significantly reduced.

3. Results and Discussion

After introducing such an additive concentration into the oil, we observed its dissolution (Table 1, 2).

### Table 1. Additive solubility results versus heating temperature

| Additive | Not dissolved | Partially dissolved | Medium dissolved | Full dissolved |
|----------|---------------|---------------------|------------------|----------------|
| zinc dithiophosphate DC-7 | 30°C | 50°C | 60°C | 70°C |

### Table 2. Additive compatibility results versus heating time

| Additive | Not dissolved | Partially dissolved | Medium dissolved | Full dissolved |
|----------|---------------|---------------------|------------------|----------------|
| zinc dithiophosphate DC-7 | 35 min | 50 min | 1.8 hour | 2.5 hour |

Having determined the dissolution of additives in oil and the dithiophosphate additive DC-7, we determined the physicochemical parameters of motor oil for various concentrations of additives.

As the object of study was selected: base oil MG-30 - with different contents (0.5, 0.7, 0.9, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0%) of DC-7 additive, which strongly affects the antiwear and antioxidant properties of oils.

The figure shows the changes in the physicochemical parameters of the tested oil depending on the percentage concentration of DC-7.
a) Viscosity, mm² / s at t = 40°C

b) Alkaline number, mg KOH / g

Content DC-7
According to the results of laboratory studies, when the additive was added to the MG-30 oil, physico-chemical parameters gave positive results compared to the base oil.

From the results of the analysis, we selected the content of additives DC – 7 1.5%, which shows the optimal value of viscosity and flashpoint. With a further increase in the concentration of DC-7, the viscosity increases significantly, which can lead to increased friction losses. With increasing viscosity, the thickness and resistance to mechanical stresses of the oil layer between the rubbing surfaces increase. Then, the physicochemical properties of oils with a 1.5% additive DC-7 were determined.

For the experiments, hydraulic oil was subjected to analysis according to physicochemical parameters following the requirements and standards of State standard 10541 (Table 3).

![Flash temperature](image)

**Figure 1 a, b, c.** Change in the physicochemical parameters of the tested oil depending on the concentration of DC-7

| Table 3. Laboratory Results | Results | Norm according to State standard | Method trials |
|-----------------------------|---------|----------------------------------|---------------|
| Name of indicator           | MG-30   | MG-30 + 1.5% DC-7                |               |
| Viscosity, mm²/s at t=40°C  | 28      | 32                               | 28.4 ± 41.4   |
| Density at 20°C, g/sm³      | 0.890   | 0.892                            | no more than 0.905 |
| Flash point, °C             | 215     | 224                              | 224           |
| Pour point, °C              | -35     | -33                              | -30 ± -42     |
| Water content, no more      | Traces  | -                                | traces        |
| The content of the fur. impurities,% | 0.011 | 0.008                           | no more than 0.015 |
| Acid number, mg KOH per 1 g of oil, not less than | 2.5 | 4 | 2.5 ± 5.5 | State standard 11362 |

State standard 33
State standard 3900
State standard 4333
State standard 20287
State standard 2477
State standard 6370
4. Conclusion
The results of laboratory studies showed that the addition of DC-7 to the base oil MG-30 gave an improved result compared with the oils used for road construction equipment MG-30. Due to the harsh operating conditions, oils for hydromechanical transmissions must have appropriate viscosity and antiwear properties.

The stock of neutralizing properties that the oil is characterized by is called an alkaline number and can vary from 5-10 mg KOH/g. The alkaline number increased from 2.5 to 4, which indicates the effectiveness of the added additive. This means that using such an additive will increase the service life of hydraulic oil.

From the comparison results, it is seen that the operational properties of the obtained sample of hydraulic oil far exceed the domestic MG-30 and meets the standards according to State standard. This is the effectiveness of the possible use of the new sample we have received. In the future, these oils can be admitted to the next stage - to operational tests on special equipment.

References
[1] Abdushukurov A A 2010 Theory of Probability and Mathematical Statistics Publ., University p 169
[2] Marchuk G I 1983 Methods of Numerical Mathematics. Nauka Publ p 196 Novosibirsk, Russia
[3] Crombie W. Process and Relation in Discourse and Language Teaching Oxford University Press p 156
[4] Godunov S K 1992 Ryaben’kiy V.S. Theory of Difference Schemes An Introduction. Publ Moscow
[5] Dym C L and Ivey E S 1980 Principles of Mathematical Modeling Publ, Academic Press p 256
[6] Ulmasov A and Vakhabov A V 2006 Theory of Economics Publ 2006 pp 480 Tashkent
[7] Godunov S K and Ryaben’kiy V S 1982 Theory of Difference Schemes An Introduction. Publ p 168 Moscow, Fizmatgiz
[8] Jacoby S L and Kowalik J S 1980 Mathematical Modelling with Computers Englewood Cliffs, N.J Prentice Hall, Inc. p 292
[9] Mavlonova R, Turaeva O and Kholikberdiev K 2002 Pedagogic p 318 Tashkent
[10] Koshlyakov N S, Gliner E B and Smirnov M M 1962 Differential equations of mathematical physics p 67 Moscow, Fizmatgiz
[11] Khodiev B Y, Bekmuradov A Sh, Gafurov U V and Tukhliev B K 2009 The book by the President of Uzbekistan, Islam Karimov, entitled The global financial-economic crisis, ways and measures to overcome it in the conditions of Uzbekistan p 120
[12] Jerichov V B 2009 Automobile maintenance materials A training manual p 256 St. Petersburg
[13] Moharramov A M, Akhmedova R A and Akhmedova N F 2009 Petrochemicals and Oil Refining Textbook for Higher Education p 660
[14] Malikov Z 2019 Effect of changes in the properties of motor oils on operation of the engine and improvement of wash-dispensing properties Proceedings of the international scientific-practical conference "New impulses of science and spirituality in world space SHYMKENT
[15] Alimova Z 2018 The influence of the process of oxidation of motor oils on engine performance and improvement of antioxidant properties ACTA TURIN POLYTECHNICAL UNIVERSITY No 1 Tashkent
[16] Makushev Y P 2006 Automobile maintenance materials Omsk, SibADI Publishing House p 58
[17] Stukanov V A 2002 Automotive Maintenance Materials Textbook, Laboratory workshop. Moscow p 208
[18] 2001 Lubricating oils and special fluids of OAO "LUKOIL" Product Directory p 128
[20] Makushev Y P 2006 Automotive Maintenance Materials Study Guide Omsk, SibADI Publishing House

[21] Syrbakov A P, Korchuganova M A 2015 Fuel and lubricants Allowance. - Tomsk: Publishing House of Tomsk Polytechnic University