Choosing of rational periodicity of engine crankcase oil changing taking into account energy-saving properties of oils

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Abstract. It is known that reducing friction losses and, consequently, wear is the most important function of engine crankcase oil. Many oil manufacturers add additives to the oil composition - thickening and friction modifiers. Achieving a rational periodicity of crankcase oil changing generally reduces the operating consumption of oil, the cost of which accounts for a significant share of the total cost structure of operating costs. The developed method for evaluating the energy-saving properties of the researched three grades of oil by viscosity-temperature characteristics allows for reducing the cost of conducting special research. The viscosity value's dependence on the temperature range from 20 to 100 °C is experimentally established. This work presents part of the research results to justify the choice of rational changing periodicity of diesel engines' crankcase oil, considering the energy-saving properties of oils. During operation, it is also necessary to comply with the requirements for preserving the recommended grades of fuel and lubricants, observing their use and safety modes, and a reasonable oil level in the crankcase.

1 Introduction

Many factors, such as climatic and road conditions, speed and load modes, driving quality, fuel equipment adjustments, the engine's cylinder-piston group (CPG), and filter elements status, etc. influence the change in the oil condition during the operation of the engine [1, 2].

The high-quality technical systems production, including vehicles, does not guarantee their long service life. A necessary condition is to ensure high-quality operation, which is associated with the necessary technical impacts on maintenance service and repair. Ensuring the use of high-quality crankcase oil is an integral part of this process [3].

On the other hand, crankcase oil and other lubricants are carriers of operational information about the technical condition of engine systems and mechanisms. By analyzing changes in oil quality indicators, it is possible to predict the engine's service life and plan the need for technical impacts on maintenance service and repair [4, 5].

We all know that friction losses are largely determined by the oil's viscosity. Moreover, the oil's viscosity varies not only from temperature but also depending on the operating

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mode of the engine parts and mechanisms, i.e., the speed of movement of the oil layers in the lubricating film.

Specially produced energy-saving oils have thickening additives and friction modifier additives [6].

Currently, great importance is being paid to reducing fuel consumption and, consequently, emissions of harmful exhaust gases, so assessing energy-saving properties recommended for using oils is important.

It is known that the crankcase oil change is carried out due to a decrease in its quality. Moreover, the oil's quality, like any product's, should be stable during the period between the corresponding changings [7].

On the other hand, the stability of oil indicators largely depends on the quality of the corresponding elements of the lubrication system, cooling, and air treatment, as well as on the quality of the technical impacts performed on them under appropriate maintenance service.

Achieving a rational periodicity of crankcase oil changing generally reduces the operating consumption of oil, the cost of which accounts for a significant share of the total cost structure of operating costs.

2 Methods

Many research related to the establishment of rational periodicity offer various solutions, including using universal synthetic oils and adding various additives to them during operation [8, 9].

Formally, the process of establishing the periodicity of crankcase oil changing may have the following options:

The first option includes recommendations from the manufacturer of the vehicle. According to the manual [10], the manufacturer recommends seasonal or all-season engine oils, which are produced by various plants in the petrochemical industry in Europe.

Oil changing in the engine lubrication system is recommended during the 2-nd maintenance service, and in the Unitary Enterprise of the specialized association for the construction of automotive roads "Avtomagistral" (Uzbekistan), the periodicity of the 2-nd maintenance service for trucks is accepted 20000 km, taking into account the classification of the operating conditions used of the MAN TGS 33.360 trucks [11].

However, the following factors are not taken into account:

- Residual oil life;
- The possibility of using oils produced in this region;
- The possibility of importing the required oils, requiring foreign currency financing;
- Maximum permissible values of wear products in oil;
- Resource-saving properties of the oil used.

The second option includes scientific and practical work to determine the rational periodicity of crankcase oil change using oil.

At the same time, the determination of the rational frequency of crankcase oil changing can be carried out, taking into account the research results following the requirements of Russian State Standard GOST 8581.

In this case, the analysis of changes in oil indicators is carried out depending on the car's mileage and following the marginal changes in the values of their indicators and recommends the optimal periodicity of crankcase oil changing [12].

This option does not take into account the following:

- Residual oil life;
- Maximum permissible values of wear products in oil;
- Resource-saving properties of the oil recommended for use.

Taking into account these researches results, a method for determining the optimal periodicity of crankcase oil changing has been developed and proposed, taking into account the following:

- Residual oil life;
- Resource-saving properties of the recommended oil for used vehicles in urban conditions.

Experimental research on the choice of oils and the determination of their rational changing periodicity were carried out based on complex analyses, including standardized methods for analyzing the main indicators of oils and spectral analysis of the content of various metals in their composition with an assessment of their resource-saving properties.

This method is conventionally called – standard tribospectral analysis of crankcase oil indicators, which determine the rational changing periodicity of a diesel engine's crankcase oil operated in urban conditions.

The oils that have been researched by this method then undergo a comparative assessment of the energy-saving properties according to the above-developed method.

The proposed method is implemented as follows. According to the schedule of oil sampling and their analysis, the indicators of the researched oils are determined following GOST 8581 and TU 17479.1, according to which their specific values and actual deviations from the recommended standards are established. However, the obtained results do not yet allow us to determine the degree of resource exploitation of this oil and its resource-saving properties. In this regard, along with the definition of the main standardized indicators, their spectral analysis is also performed.

Most experimental data was carried out on stands simulating the harsh working conditions of the cylinder-piston group parts of forced internal combustion engines and directly on operating diesels under operating conditions.

Special attention is paid to the topical issues of the influence of various additives to motor oils on the performance of tribo-couplings. Increased wear of the cylinder-piston group is characterized by a large breakthrough of gases into the crankcase, which contributes to the contamination of the oil with organic impurities [13, 14]. Moreover, fuel can play a much greater role in forming pollutants than oil. Factors such as a sharp (up to 10 times or more) decrease in the degree of contamination of oil and parts when converting engines from liquid to gaseous fuel, with the same thermal and mechanical tension of the engines, indicate the possibility of a predominant influence of fuel on the number of organic pollutants entering the oil.

3 Results and Discussion

As a rule, in diesel engines, with stable operation of fuel equipment and a sufficient reserve of antioxidant properties of an oil, the decrease in oil viscosity, as a result of fuel ingress, is compensated by its increase due to the accumulation of pollution products, i.e., the viscosity is almost constant or slightly increases.

In engines that are in working condition but characterized by a large operating time, the aging processes are intensified so much that the probability of independent oil failures increases significantly.

It was defined that when the engine is running at a reduced thermal mode, about 94% of all organic impurities in the oil are products of incomplete fuel combustion.

Thus, a change in the viscosity characteristics of the oil can lead to increased engine wear, a decrease in their power, deterioration in fuel efficiency, an increase in oil consumption for carbon monoxide, etc.

The main properties characterizing the oil's quality are determined per existing regulatory documents. However, the indicators above are determined by the developed method based on the research objectives.

The viscosity value's dependence on the temperature range from 20 to 100°C is experimentally established. The viscosity was determined every 20°C, and the viscosity-temperature characteristics of oils reflecting curves were drawn (Figure 1). Temperatures from 20°C to 100°C are the conventionally accepted temperature limit for oil operation in the engine.

The obtained graphical data were subjected to statistical processing using Microsoft Excel application programs, which allowed us to determine regression equations for the researched (GPN 15w-40, GPN 10w-40, and VT 10w-40) and reference (recommended by the manufacturer) oils.

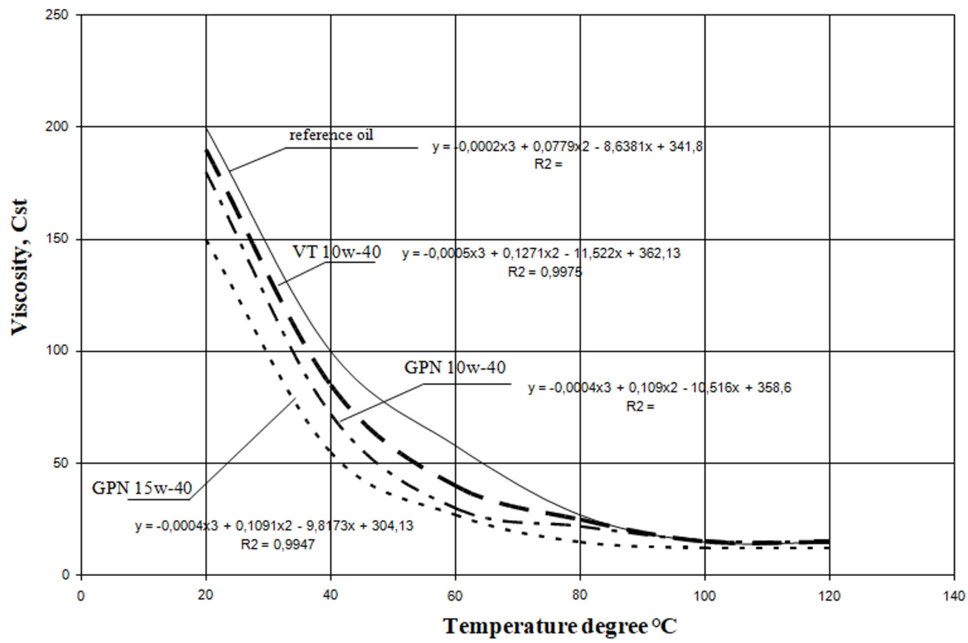

Fig. 1. Viscosity-temperature characteristics of researched oils.

Figures 2-4 show, as an example, the viscosity parameters of the researched oils depending on the mileage.

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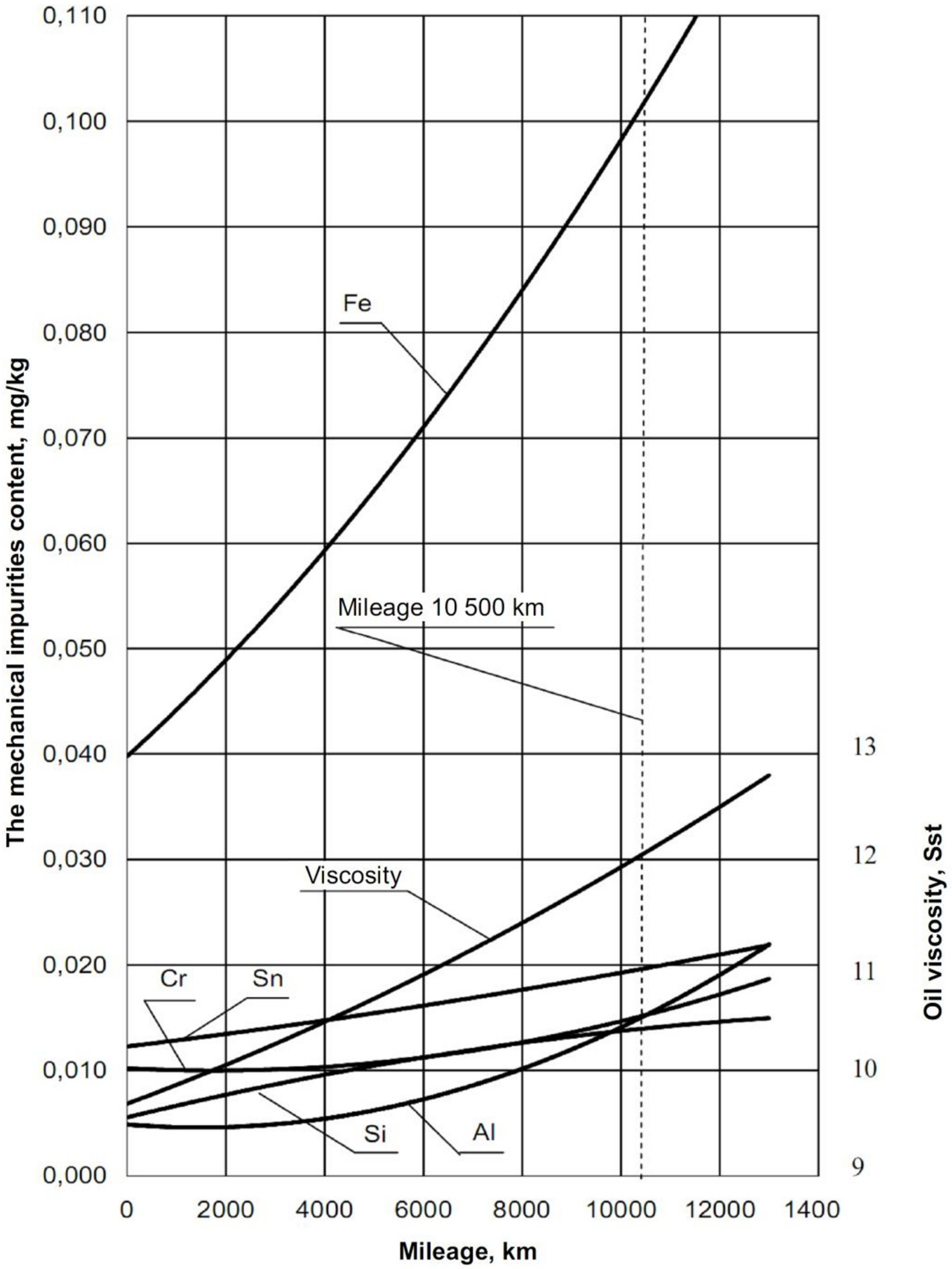

Fig. 2. Combined graphs of changes in viscosity parameter and content of mechanical impurities in GPN 15w-40 oils depending on mileage of vehicles.

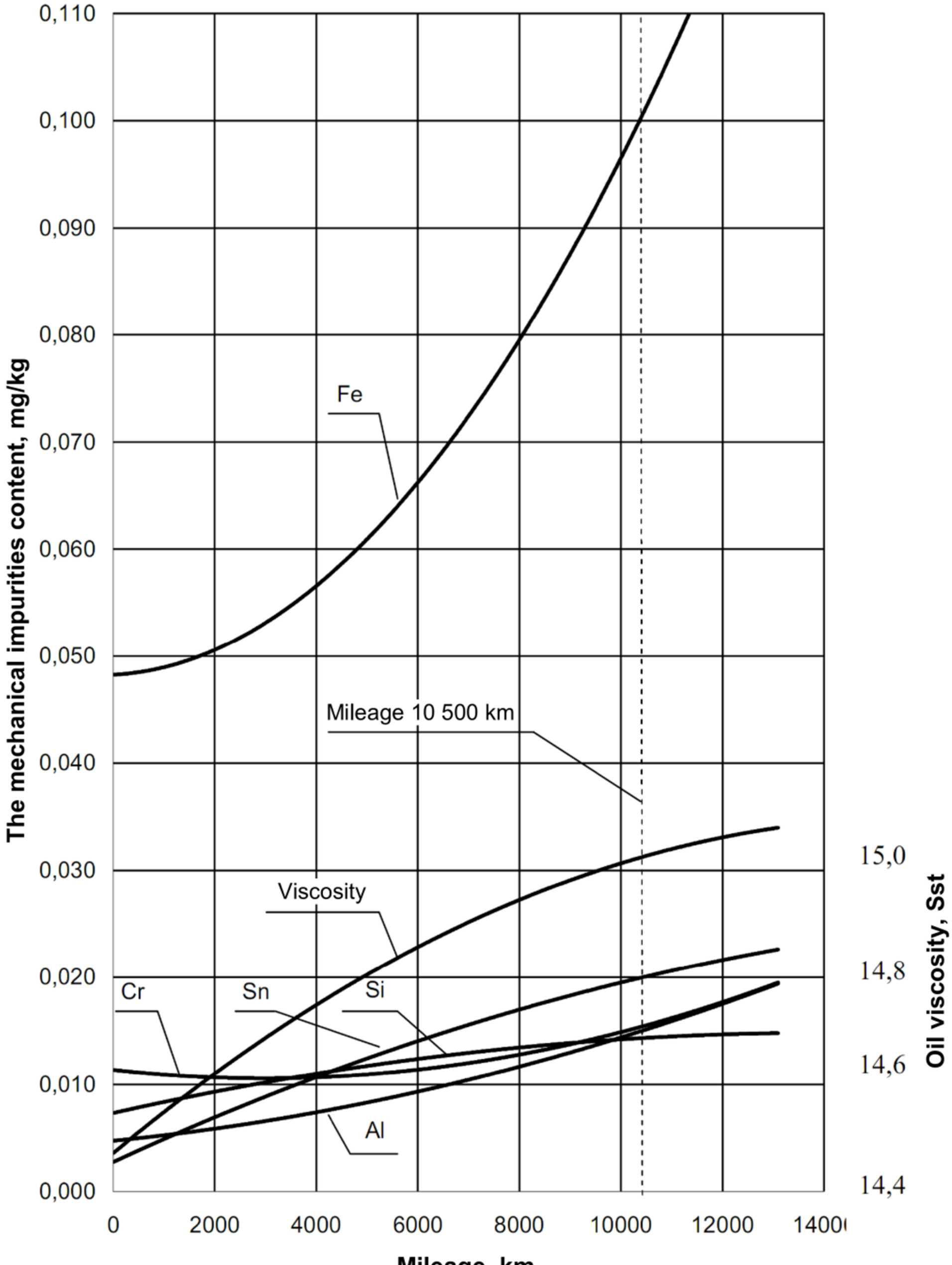

Fig. 3. Combined graphs of changes in viscosity parameter and content of mechanical impurities in GPN 10w-40 oils depending on mileage of vehicles.

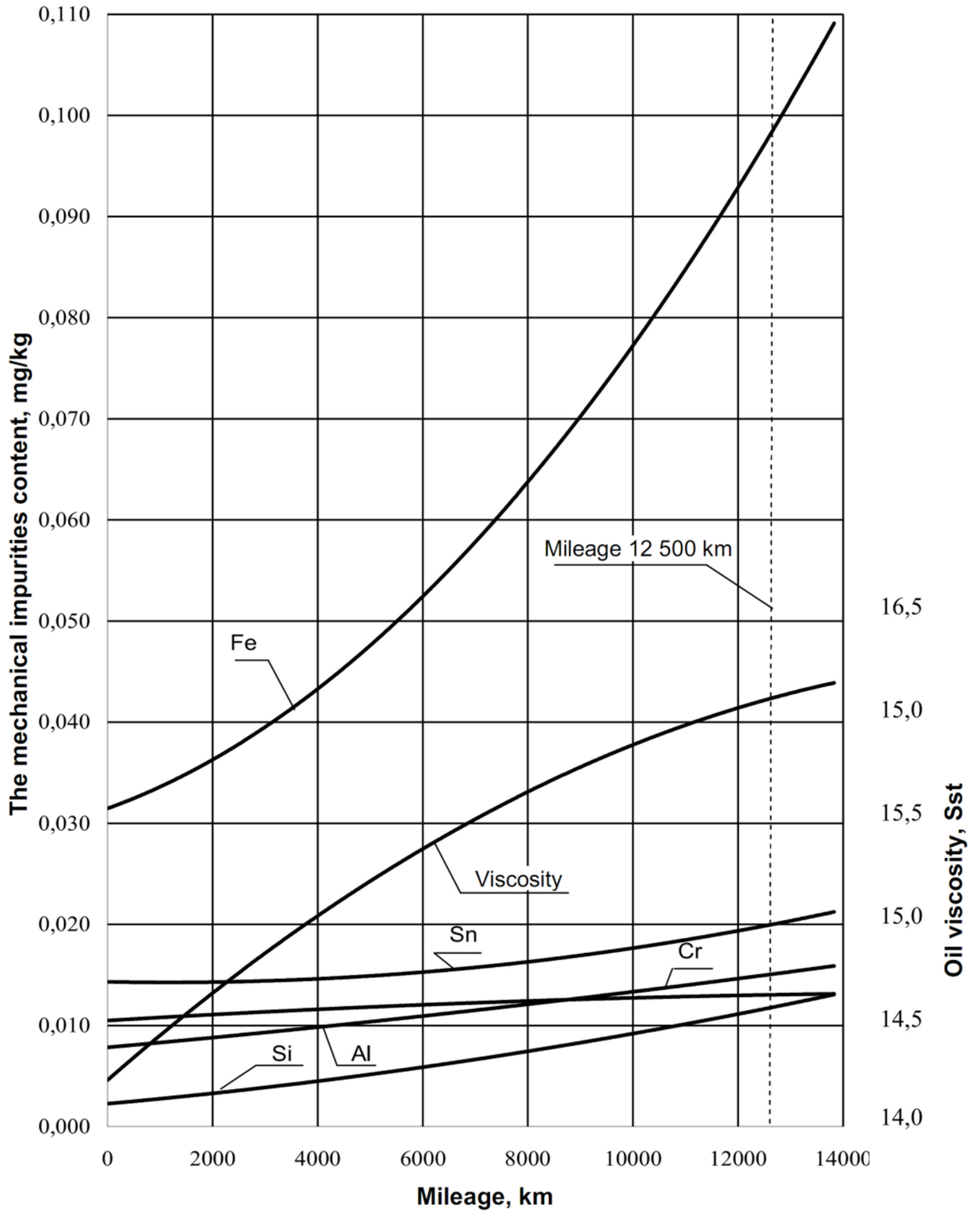

Fig. 4. Combined graphs of changes in viscosity parameter and content of mechanical impurities in VT 10w-40 oils depending on mileage of vehicles.

Preliminary research has shown that incorrectly selected oils lead to premature failure of car engines, including those operating in urban conditions [16].

As can be seen from Figures 2-4, according to the manufacturer's recommendations, the viscosity of all oils is within acceptable limits at a mileage of 14000 km of the car. However, according to the results of spectral analysis, it can be seen that in terms of tin (Pb) content, the resource for GPN 15w-40, GPN 10w-40, and VT 10w-40 oils is 10500, 10500, and 12500 km, respectively. This, in turn, is confirmed by theoretical research.

Further, comparing the results of standard and spectral analyses of engine oil and the results of the analysis of their energy-saving properties (Figures 2-4), it should be concluded that for GPN 15w-40 oil, the changing periodicity is 10500 km, for GPN 10w-40 oil 10500 km, and for VT 10w-40 oil 12500 km.

It is known that reducing friction losses and, consequently, wear is the most important function of crankcase oil. The greatest energy losses to overcome friction occur in piston engines in 3 groups: cylinder-piston, crankshaft bearings, and timing mechanism, where friction and lubrication conditions differ significantly [18].

The friction force in the cylinder piston and bearings groups mainly depends on the oil's viscosity, which determines the energy-saving properties of the oil. The higher the energy-saving property of the oil, the lower the fuel consumption and, consequently, less emission of harmful substances from the exhaust gases of the engine.

Many oil manufacturers add additives to the oil composition - thickening and friction modifiers [19].

According to the API classification, after specifying the viscosity class according to SAE and the category according to the conditions, put two letters EC (Energy Conserving), for example, SAE 5W-30, API SL/CG-4 (EC), which, following the requirements, should ensure a reduction in fuel consumption of at least 2.5% compared to the reference oil.

As already noted above, the developed method for evaluating the energy-saving properties of the researched three grades of oil by viscosity-temperature characteristics allows for reducing the cost of conducting special research. The assessment is summarized in Table 1.

Table 1. The researched oils comparative evaluation

№	Compared indicators	Descrip-tion	Measure-ment unit	Oils brand			
				The standard	GPN 15w-40	GPN 10w-40	VT 10w-40
1	Area η=f(t) for the changing period	S	mm^2	4269	3299	3659	4212
2	Recommended changing periodicity	P_{ch}	thousand km	14000	10500	10500	12500
3	The amount of oil consumed, taking into account topping up	Q_o	l/100 km	42	44	44	42
4	The total amount of oil consumed for a year	∑Q	t	0.229	0.320	0.320	0.255

These data were recorded in both working and fresh motor oils. The analysis was carried out under the following conditions:

1. The mileage before replacement during the operational tests of engine oils should be at least 10 thousand km.

2. Storage of controlled vehicles for the entire testing period - free of charge in an open area.

3. Tests are carried out according to the agreed Methodology, considering the current state, industry standards, and regulations.

4. When performing control measurements, the instrumental base of the branch laboratory of the Vehicles and automotive industry department is used.

5. Evaluation of the effectiveness of changes in the operational properties of motor oils is carried out by comparing the indicators obtained during testing with the requirements of regulatory documents.

From the obtained results, it can be concluded that of the three oils researched, oil - VT 10w-40 has a great energy-saving properties compared with the reference resource decreased by 22%.

Summarizing, it should be noted that:

- the quality of engine oil has a significant impact on the reliability of an automobile engine;
- indicators characterizing the quality of motor oils change during the operation of an automobile engine;
- the reliability of automobile engines is significantly influenced by the nominal (initial) values of the parameters of the technical and operational properties of fresh motor oils and their changes depending on the operating conditions;
- engine oils produced by various companies have an individual set of parameters of technical and operational characteristics;
- the parameters of the characteristics of used engine oils can be largely restored.

4 Conclusions

As a rule, in diesel engines, with stable operation of fuel equipment and a sufficient reserve of antioxidant properties of the oil, the decrease in oil viscosity, as a result of fuel ingress, is compensated by its increase due to the accumulation of pollution products, i.e., the viscosity is almost constant or slightly increases.

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