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Comprehensive Evaluation of Synthetic Motor Oil

The paper presents studies of the main physical and chemical indicators of the operation of synthetic oils. The following indicators were determined: kinematic viscosity at 100°C, viscosity index (IV); general base indicator, mg KOH/1g of oil, ignition temperature in an open crucible, °C, absolute density, g/cm3 (at t° at 20°C), dynamic viscosity and sulfonated ash content (%). In addition, comparative studies of the technical and economic indicators of regulatory and technical maintenance when changing engine oil were carried out.
kinematic viscosity, viscosity index, alkalinity index, flash point, absolute density

Formulation of the problem. Lubrication, an absolutely necessary process for any transport unit or mechanical structure with moving parts, concerns technicians of all types, from educational, research and development offices to simple or the most complex industrial systems. Lubricants are involved in all processes related to movement. The quality of lubricants determines the operation of machines and their reliability.

Correct selection of a lubricant is a complex action, determined by a number of factors that must be taken into account: design factors (type of tribosystem, its accessibility for lubrication, quality and quantity of lubricant, method of lubrication, etc.), operating mode factors (load, speed, etc.). etc.), environmental factors (ambient temperature and pressure, presence of pollution, etc.).

For a long time it was believed that the best substances with lubricating properties were: animal fats and vegetable oils. With the development of internal combustion engines, mineral oils (from petroleum) appeared.

Modern powerful machines, complex mechanisms and automatic machines, and the development of jet technology place great demands on lubricants, and in this case, mineral oils do not satisfy these requirements.

For modern technology, it is necessary to use oils that operate in the temperature range (-120°C – +500°C), which can withstand very high loads and speeds and are resistant in aggressive environments.

Analysis of recent research and publications. Technical progress is closely related to improving the quality of lubricating oils and the development of new types of oils that meet the increased requirements of modern technology (including for cars).

Scientific research in various directions is carried out by the science of cymatology, namely [1, 2]:

- study of oil operating conditions in engines and new machines;
- study of the chemical, physical and operational properties of lubricants;
- behavior of oils and changes in properties in engines during transportation;
- development of new methods of testing, studying and monitoring oil quality;
- study of patterns of changes in oil quality in internal combustion engines or cars.

Statement of the task. The purpose of the work is study of physicochemical and performance characteristics of synthetic oils used in automobile engines. This can happen in two ways:

a) study of the main physical and chemical parameters of the oil;

b) determination of the quality of oils by a generalized complex indicator (Kkg) which consists of the sum of indicators of the diagnostic block of the determining one (Ki).

Presentation of the main material. Testing of synthetic oils is a complex and multifaceted process, during which the main physical and chemical parameters of the oil are determined and studied [3], namely:

- kinematic viscosity at 100°C in sSt in accordance with ASTM D 445;
- viscosity index (IV);
- general base index (BBP), mg KOH/1 g of oil according to ASTM D 664;
- ignition temperature in an open crucible, 0C according to GOST 1369-82;
- absolute density, g/cm3 (at t at 20°C);
- dynamic viscosity;
- sulfonated ash content, % according to ASTM D 874.

These parameters are basic, and assessment methods are standardized [3].

To evaluate the performance properties of synthetic oils, research test methods are used to determine resistance to thermal oxidation - resistance to the formation of acids and resins at high temperatures.

It is known that resins on warm surfaces form carbon formations that cause intense engine wear and blocking of segments. Oxidation products cause corrosion of engine parts and accelerate the aging of rubber sealing materials.

When determining the stability of oil during thermal oxidation, in this case, oil oxidation is carried out at high temperatures corresponding to the temperature of the first compression segment of piston engines.

This method is used at the Bo-4 installation, where the oxidation of motor oil is carried out at t = 180°C. This method corresponds to the operating conditions of medium-boost car engines.

Modern highly accelerated automobile engines require more stringent oil conditions, and the oil's thermal oxidation requirements increase. Oil oxidation occurs at t = 235°C in the presence of a Cu catalyst. The stability of the oil during thermal oxidation is assessed by the increase in the optical density of the oil, which characterizes the increase in the amount of oxidation products in the oil.

Synthetic oils of viscosity classes SAE 5W-30 and SAE 5W-40 were tested, corresponding to API SM, SL, SJ; ACEA A3/B3/B4.

Tested brands of synthetic oils.

- LIQUI Moly synthoil High Tech Germany – viscosity class: SAE 5W – 40; API SM/CF; ACEA A3/B4, recommended for BMW Longlife-98, MB 229.3, Porsche A40, VW 502 00, VW 505 00;
- Elf Evolution 900SXR 5W-40; API SM/CF; ACEA 2007: A3/B4, recommended for RENAULT: RN0710, RN0700 - gasoline (including turbo) and diesel engines without particulate filter;
- Mobil Super™ Synthetic 5W-30 Saudi Arabia; API SN; API SN PLUS; API SP; ILSAC GF-6A; FORD WSS-M2C961-A1, recommended for use in many types of gasoline cars of modern and earlier design in America (Ford, GM, Chrysler...), Japanese (Toyota, Nissan, Mistsubishi) and Korean (Hyundai, Kia);
- SHELL Helix Ultra Finlandia; - viscosity class: SAE 5W – 40; API SN/CF; ACEA A3/B3, A3/B4; BMW LL-01; recommended for MB 229.5, 226.5; VW 502.00/505.00;

Porsche A40; Renault RN0700, RN0710; PSA B71 2296, Ferrari. Complies with Fiat 9.55535-Z2 and Chrysler MS-10725.

The main function of motor oil (including for various other machines and equipment) is to prevent wear and excessive friction. Although other oil characteristics such as dispersibility, thermal stability, corrosion resistance, etc. are important, the ability to lubricate moving parts remains the main parameter for the use of a lubricant.

It is known that in modern conditions, during the operation of engines and various machines, a large amount of energy is lost due to friction, even with their lubrication provided. Due to the tribological and technological design, it was possible to save 11% of annual energy consumption.

Although mineral oil technology and lubricant formulations with the necessary additives have achieved certain advances, synthetic oils currently serve as automotive lubricants, either alone or in a mixture with mineral oils. When comparing the properties of mineral oils with the properties of modern types of synthetic oils, it was found that synthetic hydrocarbons and esters provide the best performance. Their cost is 1.5-2 times higher than that of conventional mineral oils.

The main applications of synthetic oils, which are more important from a production point of view, are shown below.

The qualitative characteristics of the tested synthetic oils are presented in Table 1.

Table 1 – Qualitative characteristics of synthetic oils

Options	**SAE 5W-40 „LIQUI Moly”** synthoil High Tech	**SAE 5W-40 „SHELL Helix Ultra”**	**SAE 5W-30 „Elf Evolution”**
Match the classes	API SM/CF; ACEA A3/B4	API SN/CF; ACEA A3/B3, A3/B4	API SM/CF; ACEA 2007: A3/B4
Kinematic viscosity at 100°C, sSt	14,0	14,2	14,0
Viscosity index	167	175	180
Density at 20°C, g/cm3	850	855	848
Flash point, °C	210	220	226
Alkalinity index, mg KOH/g, oils	9,8	7,5	7,2
Freezing temperature, °C	-40	-40	-30
Ash content, GOST 1461-75	1,5	1,3	1,1

Source: developed by the author

Physic-chemical parameters of oils: density, kinematic viscosity, viscosity indices, alkalinity, ignition temperature vary depending on their viscosity class.

The recent rise in oil prices has generated increased interest in fuel efficiency. It has long been known that fluid oils can significantly save fuel in automobile engines, but these oils have high consumption (high volatility) and do not provide sufficient wear protection. Since synthetic oils do not have these disadvantages, some European manufacturers have developed motor oils based on synthetic oils or blends with mineral oils, which have given good results in operation.

Numerous studies on the use of synthetic oils as motor oil bases, alone or in mixtures with mineral oils, have shown the interesting possibilities of esters. Mixtures with diesters in a proportion of 10 - 50% in mineral oils, with appropriate additives (antioxidant, detergent-dispersant, polymethacrylate for viscosity index, etc.) provided all-season oils, successfully tested on engine test benches and in operation, especially in cold climates. By increasing the proportion of diester, a better degree of cleanliness of engine parts is achieved. The benefits of diester oils for cold starting of engines have been fully confirmed.

Recent tests on a large number of vehicles with synthetic oil SAE 5W-20 compared to two mineral oils SAE 10W-40 and SAE 15W-50 have shown numerous advantages; 4-5% fuel economy, oil change after 40,000 km, easy cold starts, cleaner engine, less wear, low oil consumption, more nervous engine. The corresponding SAE 75W synthetic differential oil, with a low viscosity compared to SAE 80W-90 oil, resulted in fuel savings of approximately 2%.

Synthetic non-hydrocarbon based oils attack many of the elastomers from which gaskets are made or, sau represent relatively hydrolytic stability, etc. A process based on the conversion of petroleum hydrocarbons into a suitable form will, of course, be more economical than the production of diesters, etc. Synthetic hydrocarbons will further benefit from 30 years of additive manufacturing experience. In the near future, diesters are expected to be used in small quantities in relatively fluid all-season automotive oils with additives and friction modifiers.

The lack of accurate indicators of engine oil rejection in tractor, automobile and combine engines leads to an unjustified reduction in its service life, causing wear of parts and increasing operating costs for lubricants.

It is proposed to evaluate the condition of the oil using a generalized complex indicator (K_{cg}), which consists of the sum of indicators that determine the diagnostic unit Ki. A defining diagnostic indicator is selected, analyzing the effect of each of them on engine operation. In particular, on the wear rate of parts. Random variations of the parameter (wear rate) Ufrom (t) are written as a function U_{is} (e)= $f(\alpha_1;\alpha_2;\alpha_3;\ldots\alpha_n)$, where α - is the value of the diagnostic indicator.

Based on the above, we have developed a method for assessing the quality of motor oil using a generalized coefficient that includes 6 diagnostic indicators, silicon content in the oil (additionally characterizes the operation of the air filter); mechanical impurities in the oil (characterizes the operation of oil-filtering devices), iron content in the oil, as well as its viscosity, ash content, general base indicator (GBP). Maintenance of the air purification system and oil filtration system is carried out based on the corresponding diagnostic parameter.

The K_{cg} indicator is expressed by the formula:

$$K_{cg}= \sum_{i=1}^{i=n} K_i - T\cdot d, \quad (1)$$

where K_i – indicator of the condition of the engine oil according to the i-th diagnostic indicator;

n – number of diagnostic indicators determined;

d – coefficient of intensity of variation of diagnostic indicators depending on the work performed by the engine, points/motor hours;

T – the amount of work performed by the engine, engine hours.

The oil is changed only when the generalized complex indicator of the rejection value is reached, equal to 100 points (other units of measurement can be accepted, for example, %, fractions of a unit, etc.).

To assess the intensity of its action, it is proposed to maintain an evaluation indicator - the coefficient of the oil's action mode.

$$\gamma = \frac{V_u / P_e}{Q_{h} \cdot \varphi} \cdot K_c, \quad (2)$$

where V_u – capacity of the engine lubrication system, l;

φ – dimensionless coefficient characterizing oil purification in a centrifugal filter;

K_c – dimensionless coefficient characterizing the oil group.

Because

$$\varphi = \varphi_0 \cdot (1 - \frac{m_o}{m_a}), \quad (3)$$

where φ_o – initial coefficient of oil purification in the centrifugal filter;

m_o – mass of substance deposited in an oil centrifuge, kg;

m_a – amount of impurities allowed in the centrifuge, kg.

Получим:

$$\gamma = \frac{V_u / P_e}{Q_h \cdot \varphi_o \left(1 - \frac{m_o}{m_a}\right)} \cdot K_c. \quad (4)$$

So, the oil action coefficient is indirectly (through power) related to the operating conditions of the engine oil. (such as: effective pressure in the cylinder, piston speed, crankshaft rotation speed, number of engine strokes, amount of heat released during fuel combustion).

The procedure for operational assessment of the quality condition of engine oil using the generalized complex coefficient (D241L engine) with a volume of work performed equal to 1200 engine hours is as follows:

1 – an oil sample will be taken and analyzed using known methods;

2 – using the classic nomogram, which determines the value of each parameter and determines the overall value of K_i = 60.0 points;

3 – taking into account the coefficient α=0,0149 and the work performed by the engine, T=1200 motor hours, the quality condition of the oil at the time of its use is assessed.

$$K_I = \sum_{1}^{n} K_i - T \cdot \alpha = 60 - 1200 \cdot 0{,}049 = 60 - 17{,}88 = 42 \text{ points}$$

4 - given the degree of defective condition of the oil, equal to 100 points, the oil can still be used in the future, since Kcg = 42, which is less than 100.

Comparative studies regarding the technical and economic indicators of regulatory and technical maintenance when replacing engine oil, as well as the proposed forms of control based on a generalized complex coefficient, have demonstrated that the implementation of the proposed measures ensures a reduction in engine oil consumption by 12...20%, and repair costs by 10 …20%.

Conclusions. Physico-chemical parameters: density, kinematic viscosity, viscosity index, ignition temperature of synthetic oils vary depending on their viscosity class.

Synthetic oils provide high lubricity and superior thermal stability compared to mineral oils.

When synthetic oils are used in car engines, they provide easy engine starting in cold conditions, fuel economy, low oil consumption, and oil changes after 40 thousand km.

Comparative studies regarding the technical and economic indicators of regulatory and technical maintenance and the proposed forms of control based on a generalized complex coefficient have demonstrated that the implementation of the proposed measures ensures a reduction in engine oil consumption by 12...20% and the cost of repair work by 10...20%.

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Комплексна оцінка синтетичної моторної оливи

У роботі представлені дослідження фізико-хімічних та експлуатаційних характеристик синтетичних олив, що використовуються в автомобільних двигунах. Це може досягти двома способами: дослідженням основних фізико-хімічних показників нафти та визначенням якості масел за узагальненим комплексним показником (Ккг), який складається із суми показників діагностичного блоку визначального (Кі).

Визначали такі показники: кінематичну в'язкість при 100°C, індекс в'язкості (IV); загальноосновний показник, мг КОН/1г олії, температура займання у відкритому тиглі, °C, абсолютна густина, г/см3 (при t° при 20 °C), динамічна в'язкість і сульфована зольність (%). Крім того, проведено порівняльні дослідження техніко-економічних показників нормативно-технічного обслуговування при заміні моторного масла.

Використання синтетичних масел в двигунах автомобілів забезпечує легкий запуск двигуна в холодних умовах, економію палива, низьку витрату масла, заміну масла після 40 тис. км. Порівняльні дослідження техніко-економічних показників нормативно-технічного обслуговування та запропонованих форм контролю на основі узагальненого комплексного коефіцієнта показали, що реалізація запропонованих заходів забезпечує зниження витрати моторного масла на 12...20 % і вартість ремонтних робіт на 10...20%.

кінематична в'язкість, індекс в'язкості, індекс лужності, температура спалаху, абсолютна густина

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