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Methodological Approach to the Combination of Motor Oils in Operation

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Abstract

The article considers the possibility of combining motor oils of different brands when operating motor vehicles. It is substantiated that the main reason for the incompatibility of motor oils is the conflict of additives which leads to their partial or complete deactivation. Based on the results of a laboratory study of the quality indicators of oxidized motor oil mixtures, it was established that the majority of motor oils found on the petroleum products market today are compatible or partially compatible. This is primarily due to the fact that different manufacturers of motor oils use the same classes of chemicals for the synthesis of base oils and additives. The article presents a general methodological approach to combining motor oils in the operation of automotive equipment, which will save consumables (motor oils) while maintaining the level of operational reliability of the internal combustion engine.

Keywords: *Motor oils; Additives, operating; Reliability; Combining oils; Methodological approach; Quality indicators.*

1. Introduction

During the operation of motor vehicles, the need to combine different brands of motor oils often arises. This is due to either emergency topping up of motor oil in the engine instead of the lost one, or scheduled maintenance, which involves the complete replacement of used motor oil with fresh one. The creation of a scientifically based methodological approach to determining the compatibility of motor oils in the operation of motor vehicles, on the one hand, will significantly save expensive consumable operating materials, on the other hand, it will ensure the operational reliability of the internal combustion engine (ICE).

2. The objective of the research

Today, all engine oil manufacturers state that combining oils of different brands is not acceptable and can lead to engine failure. When switching from motor oil to oils of other viscosity classes (SAE classification), performance levels (API classification) and brands, according to the recommendations of oil manufacturers, it is necessary to perform a complete flushing of the lubrication system [1], which inevitably leads to additional flushing fluid consumption and time spent on this procedure. This approach is dictated mainly by economic factors rather than scientifically based research, information about which is completely absent in the technical literature. In view of this, the issue of creating a technology for combining motor oils of different brands is a very urgent task that needs a timely solution.

3. Analysis of publications

The potential risks that may arise when combining motor oils during the operation of motor vehicles are presented in the form of a structural diagram shown in Fig. 1.

The detergent properties of engine oils characterise their ability to clean engine parts from various varnish-like deposits, carbon deposits, etc. These properties are ensured by the introduction of detergent additives containing surfactants, which detach particles of deposits from parts and transfer them to engine oil [2]. It is these additives - highly alkaline metal sulfonates (Ca, K, Na, Ba) - that characterise the total alkaline number of the oil (TBN, mg KOH/g oil) [3]. During operation, these sulfonates are consumed to neutralise the acidic components of oils, characterised by the total acid number (TAN, mg KOH/g oil) [4]. The deactivation of additives contributes to a rapid decrease in the alkaline number during the operation of oils in internal combustion engines, which is reflected in the deterioration of the detergent properties of the oil.

The lubricating properties of motor oils are their ability to prevent the wear of friction nodes due to the formation of a strong film on the rubbing surfaces, which excludes direct contact of the friction parts. There are chemical (chemisorption) and physical (adsorption) films. The formation of oil films by the forces of adsorption is caused by the presence of surface-active substances (surfactants) in lubricants that carry an electric charge. They have the ability to form rather strong layers of oriented molecules at the liquid-solid interfaces [5-6]. When additives come into conflict, they are deactivated, which significantly reduces their ability to create durable oil films on friction surfaces.

The viscosity of engine oils is one of the most important oil properties that has a multifaceted operational significance. The viscosity largely determines the lubrication mode of friction pairs, heat removal from working surfaces, gap sealing, energy losses, engine start-up speed, and oil pumping by the lubrication system [7]. Viscosity reduction when compounding motor oils occurs in cases where oils that have a very significant difference in viscosity classes (a difference of two or more classes according to the SAE classification) are used. On the one hand, the lower viscosity of the oil ensures easy starting of the engine (turning the crankshaft by the starter and pumping the oil through the lubrication system) at low ambient temperatures. However, at high temperatures, the oil must not have a very low viscosity to create a strong oil film between the rubbing parts and the necessary pressure in the system [8].

Soot formation during the operation of motor oils occurs during the intensification of the oxidation processes of oil hydrocarbons. These processes are inhibited by the work of an antioxidant additive [9], but with its insufficient concentration in the composition of the oil or partial deactivation, there is an intensive formation of hydrocarbon oxidation products - tar-asphaltenic substances [10-11]. Soot formation contributes to a deterioration in the cooling of the combustion chamber, reduces its volume, and makes it possible for the mixture to ignite prematurely [12].

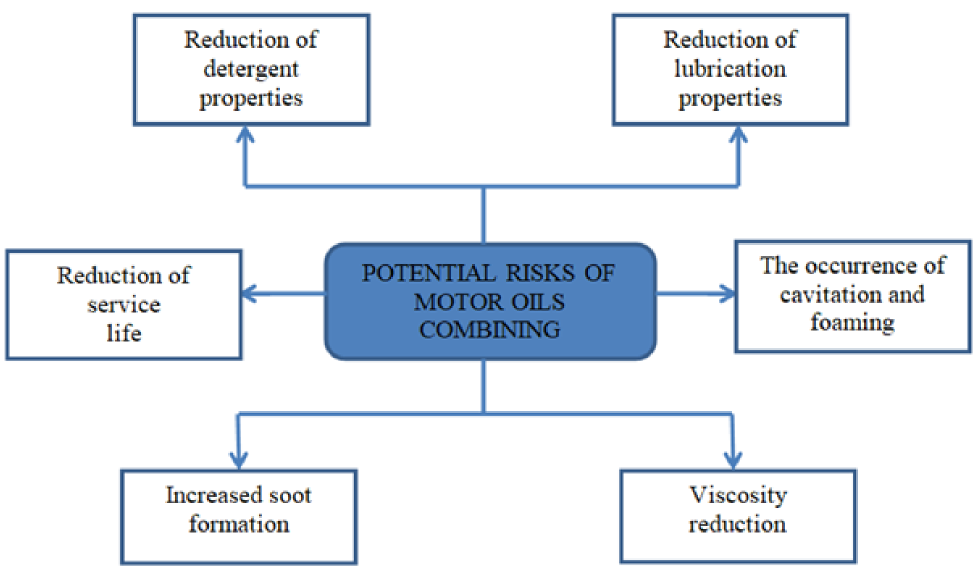

Figure 1. Potential risks that may arise when combining motor oils.

Cavitation and foaming. Cavitation is a physical process of bubble formation in liquid media, followed by their collapse and release of large amounts of energy, accompanied by noise and hydraulic shocks. Cavitation occurs as a result of a local decrease in liquid pressure [13]. During the operation of motor oils, cavitation can occur when the oil viscosity decreases and various contaminants are present in it. As for foaming, it should be noted that up to 10 % of air can be dissolved in engine oil at normal pressure [14]. The amount of air dissolved in the oil is mainly influenced by temperature and pressure. If the temperature and pressure change suddenly, the air will separate from the oil to achieve a new balance. When the separated air is surrounded by an oil film, foam forms. Another source of foam formation is the mechanical mixing of oil in contact with air [15]. The oxidation products of oil hydrocarbons - tar and asphaltene substances - can also increase the intensity of oil foaming. Cavitation and foaming processes have a negative impact on the metal surfaces of the friction pairs of an internal combustion engine due to the breakage of the protective oil film, thereby reducing the reliability and durability of the engine.

The service life of the engine oil depends significantly on its ability to perform its functions during the operation of the internal combustion engine. Extending the service life of motor oils is the main task of all enterprises and organizations related to the operation of motor vehicles [16]. But it is closely related to the potential of the additive package contained in the engine oil. It is clear that with partial deactivation of the additive package, their overall potential also decreases, which ensures maintenance of the oil's performance during a certain period of operation.

Thus, it can be concluded that all the fundamental risks when combining motor oils are mostly related to the conflict between the additive packages contained in the oils, and to a lesser extent to the nature of the base oil. Moreover, the conflict of additives, in many cases, does not appear instantly, but only during the operation of oils in the engine, when the oil is affected by a combination of various factors (temperature, pollution, catalytic action of metal. [17]. Therefore, the assessment of the possibility of combining motor oils should consist of the following stages: stage I - visual assessment of the resulting mixture (presence of mixture turbidity, precipitation); stage II - simulation of real operating conditions (laboratory oxidation of the resulting mixture); stage III - determination of quality indicators of the oxidised oil mixture. Moreover, stage I is a preliminary assessment, and if it is positive, stages II and III can be used. If stage I reveals the presence of oil mixture turbidity and/or sedimentation, there is no need to use more complex stages of the study – the oils can be recognised as incompatible.

4. Materials and methods of the research

The materials of the study were 15 samples of all-season mineral oil (SAE 15W-40 API SJ, SAE 15W-40 API SF, SAE 15W-40 API CD, SAE 15W-40 API CF) and 15 samples based on synthetic (SAE 5W-30 API SL, SAE 5W-30 API SL, SAE 5W-30 API SL/CF, SAE 5W-30 API CJ-4) basis of various global brands.

The research methods consisted of compounding laboratory oil mixtures in a 1:1 volume ratio, followed by oxidation of these mixtures at a temperature of 180-200 °C in volume due to the passage of air (up to 5 dm^3/min) through the oil to form aeration in the presence of a catalyst (copper plate). After the oxidation, the resulting mixtures were subject to visual assessment and laboratory determination of the main oil quality indicators: total alkaline number (TBN, mg KOH/g oil) according to ASTM D4662 and total acid number (TAN, mg KOH/g oil), Conradson coking point (X_c, %) according to ASTM D189-06 and wear spot diameter (D_w, mm) according to ASTM D-4172. The results obtained were compared with the results of determining the same indicators for individual motor oils, on the basis of which a conclusion was made about the compatibility or incompatibility of these oils.

5. Experimental research

Experimental studies have shown that a visual assessment of the resulting oil mixtures, both before and after oxidation, did not reveal the incompatibility of the selected motor oil samples. Therefore, further laboratory determination of the main oil quality indicators was carried out according to standardised ASTM methods. The most significant results of the studies are presented in Figures 2-7. The other results obtained, due to the rather close values of quality indicators between the oxidised oil mixture and oxidised individual oils, indicate full compatibility of motor oils.

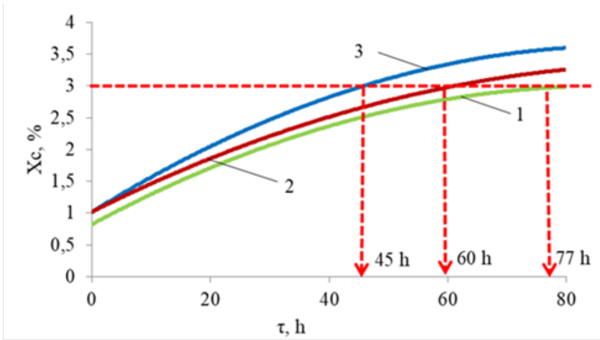

Figure 2. Dependence (X_c, %) on the duration of oxidation (τ, h) for a mixture of petrol motor oils: 1 – SAE 15W-40 API SF; 2 – SAE 5W-30 API SL;3 – oil mixture 1:1.

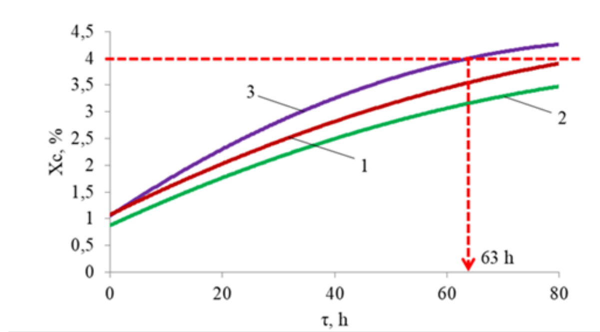

Figure 3. Dependence (X_c, %) on the duration of oxidation (τ, h) for a mixture of diesel engine oils: 1 - SAE 15W-40 API CF; 2 – SAE 5W-30 API SL/CF;3 – oil mixture 1:1.

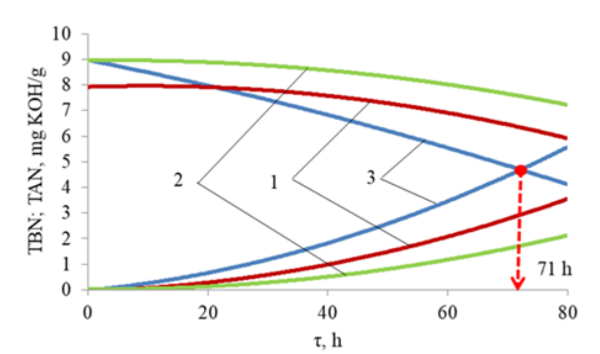

Figure 4. Dependence (TBN; TAN, mg KOH/g) on the oxidation duration (τ, h) for a mixture of petrol motor oils: 1 – SAE 15W-40 API SF; 2 – SAE 5W-30 API SL; 3 – oil mixture 1:1.

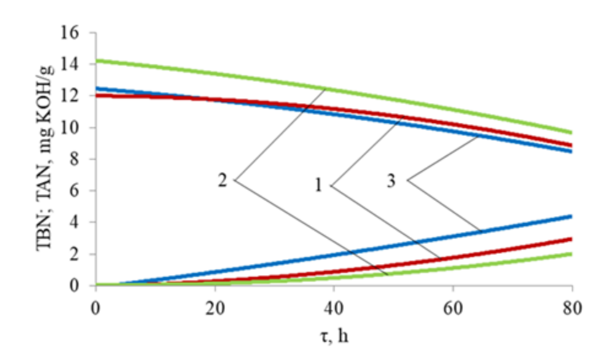

Figure 5. Dependence (TBN; TAN, mg KOH/g) on the oxidation duration (τ, h) for a mixture of diesel engine oils: 1 – SAE 15W-40 API CF; 2 – SAE 5W-30 API SL/CF; 3 – oil mixture 1:1.

Note that we did not determine such a quality indicator as kinematic viscosity for oxidised mixtures (ν, mm^2/c). It is known that to ensure the required viscosity over the entire operating temperature range, motor oils are made from a low-viscosity base (base oil) and polymeric additives that thicken it [18]. The molecules of thickening additives are in the form of 'tangles' of polymers (substances whose molecules consist of a large number of repeating links), which swell when heated, allowing the oil to maintain sufficient viscosity at elevated temperatures. When combining oils, the viscosity of the mixture will never be less than the viscosity of one of the components of the mixture. And thickening polymer additives are compatible with other types of additives [19]. In view of this, the kinematic viscosity can always be calculated, so in this case, it is of secondary importance compared to other quality indicators.

Having analysed the data presented in figures 2-7, we note that they can be considered conditionally compatible, since their mixtures lose their performance faster than individual motor oils - the components of this mixture. Diesel engine oil mixtures are characterised by a higher level of performance than oils for petrol engines, as evidenced by the quality indicators studied. Thus, according to the indicator (X_c, %), a mixture of motor oils for petrol engines reaches a rejection value (3 %) [20] at 45 hours of oxidation, while this indicator of a mixture of motor oils for diesel engines reaches a rejection value (4 %) [20] at 63 hours of oxidation. When studying the indicators (TBN; TAN, mg KOH/g), it should be noted that an oil or oil mixture is considered inoperable under conditions when TBN=TAN [20]. This is exactly what is observed in the case of an oxidised motor oil mixture for petrol engines. These conditions are fulfilled at 71 hours of oxidation of the oil mixture, while this is not the case for the diesel engine oil mixture.

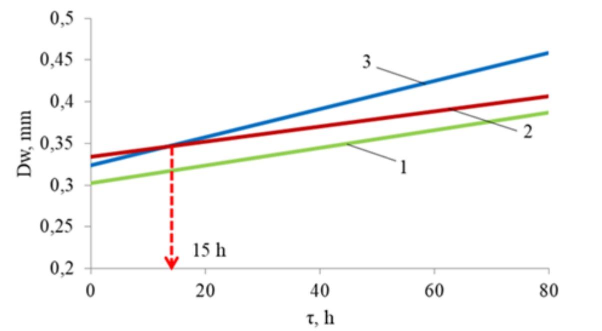

Figure 6. Dependence (D_w, mm) on the duration of oxidation (τ, h) for a mixture of petrol motor oils: 1 – SAE 15W-40 API SF; 2 – SAE 5W-30 API SL; 3 – oil mixture 1:1.

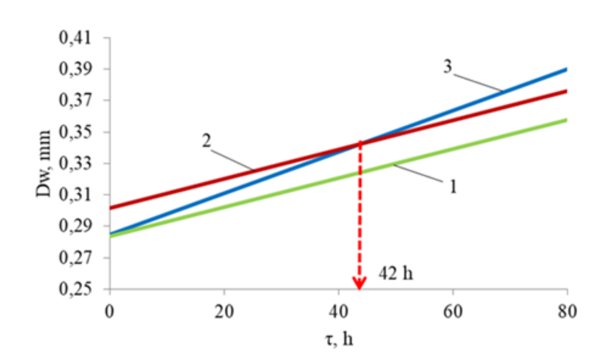

Figure 7. Dependence (D_w, mm) on the duration of oxidation (τ, h) for a mixture of diesel engine oils: 1 – SAE 15W-40 API CF; 2 – SAE 5W-30 API SL/CF; 3 – oil mixture 1:1.

The lubricating properties of motor oils for diesel engines as well as their mixtures deteriorate (become worse than the original components of the mixture) at 42 hours of oxidation, in contrast to motor oils and their mixtures for gasoline engines (deterioration of the properties of oil mixtures is observed already at 15 hours of oxidation).

It is clear that the conducted studies are significantly different from the real conditions of operation of motor oils and their mixtures because they do not take into account the effects of many factors (for example, the technical condition of the internal combustion engine, the culture of car operation, pollution of the motor oil), which contribute to shortening the period of their operation. However, as an additional step towards the final scientifically based solution to the issue of engine oil compatibility, it has the right to exist.

6. Conclusions

Thus, on the basis of the conducted research, it is possible to formulate the following methodological approach to combining motor oils:

1) The combination of motor oils is a forced step only when preventing an emergency situation when operating an internal combustion engine.

2) All the fundamental risks that can arise when combining motor oils are mainly related to the conflict between the additive packages contained in the oils, and to a lesser extent to the nature of the base oil. That is, motor oils with different kinematic viscosities can be combined with each other, but only if the difference in SAE viscosity is no more than two classes.

3) Completely incompatible engine oils were not found in the course of the research, which is due to the use of the same classes of chemicals that are used today as a base and additives by different manufacturers of engine oils.

4) All tested motor oils, which are produced today by well-known brands and purchased from licensed sales outlets, can be considered either fully compatible or partially compatible. With partial compatibility of motor oils, the service life of their mixture should be no more than 2/3 of the period recommended by motor oil manufacturers.

5) If it is impossible to carry out a qualified study on the compatibility of different brands of motor oils, in order to ensure reliable operation of the internal combustion engine, oils of the same brand should be used. If it is impossible to use oils of the same brand, the content of one of the oils in the composition of the other should not exceed 15-20 %.

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