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Analysis of Promising Methods and Tools for Monitoring the Condition of Engine Oil During Transport Technics Operation

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***Abstract.** The article discusses the main directions of research in the field of monitoring the condition of engine oil during its operation. The most promising methods of assessing the condition of engine oil are highlighted. The main factors affecting the resource of engine oil are determined. The comparison of recommended engine oil change intervals depending on the type of vehicle, climatic and road operating conditions is carried out. The criteria for comparing equipment for express assessment of the state of oil in the internal combustion engine are determined. The results of a comparative evaluation of the equipment according to certain criteria are presented.*

***Keywords:** automotive transport, internal combustion engine, lubrication system, motor oil monitoring, change interval, motor oil resource.*

Introduction

The efficiency, reliability and durability of road building machines largely depends on the correct choice of the used grades and brands of fuel and lubricants and its quality, which, in turn, depends on cleanliness. One of the main lubricants used in automotive transport is motor oil. Its function is not only the lubrication of rubbing parts, but also the removal of heat from the internal combustion engine (in places of friction), protection of parts from corrosion (oil forms a protective film that protects the metal from rust), as well as cleaning of internal combustion engine parts when oil circulates through the lubrication system. Engine oil changes its physical and chemical properties during operation, and becomes contaminated by small mechanical particles. Used engine oil is subject to change and subsequent processing (regeneration for reuse, production of preservation materials to protect metal structures from corrosion, production of fuel oil, fuel production, use for hydrophobization of building materials, etc. [1-4]).

Timely replacement of motor oil allows to extend the service life of internal combustion engine (ICE) parts and, accordingly, reduce the cost of its repair. Automative transport manufacturers indicate in the technical documentation the recommended period of change for motor oil and other technical fluids.

Often, under normal conditions of operating the internal combustion engine and compliance with the intervals between oil changes recommended by manufacturers, physical and mechanical characteristics of motor oil during operation are within acceptable limits. In the future, if the condition of the motor oil is maintained properly (which can only be confirmed by constant monitoring), the interval between oil changes can be increased. On the other hand, the recommended oil change intervals don't take into account the specifics of the operation of motor vehicles. Depending on the road and climatic conditions, the operating mode, as well as the used type of fuel [5], the standard maintenance regulations (including the frequency of motor oil change) can be adjusted both downwards and upwards [6].

In this regard, the task of determining the optimal time for engine oil change and technical means of monitoring its condition is very urgent.

The purpose of research is to determine the optimal method and equipment for monitoring the condition of engine oil in the internal combustion engines under operating of transport technics.

To achieve this purpose, the following tasks were consistently solved:

- determination of the main factors affecting the condition of engine oil during the operation of transport technics;

- development of proposals to use the equipment for operational monitoring of the dynamics of changes in the quality of engine oil in the internal combustion engines;

- determination of the main indicators for assessing the condition of engine oil;

- comparative evaluation of different models of equipment for express control of engine oil during operation of transport technics.

The scientific novelty of the paper consists in:

- the results of the analysis of promising methods for monitoring the condition of fuel and lubricants in the period of operation of transport technics;

- determination of the set of factors affecting the resource of engine oil;

- the proposed set of criteria for comparing equipment for express evaluation of the condition of oil in the internal combustion engine.

The practical usefulness of the study lies in the developed recommendations for the selection of equipment for express monitoring of the condition of engine oil in internal combustion engines.

Research methods

A large number of domestic and foreign scientists researches, such as [5-10], are devoted to the study of the issue of control the quality of fuels and lubricants by various methods. In their research, the authors used methods such as assessing the resource of motor oil by an autotransfer (by the balance of acid and alkaline numbers) [5], determination of the engine oil change interval of gasoline engines based on the actual operating time [6], tribological studies [7], optical, electrical (using Kautler-Kounter counters) methods, X-ray photometry, emission spectroscopy, quantitative molecular spectral analysis method based on the Booger-Lambert-Behr law, flow ultramicroscopy, acoustic analysis, polarography, chromatography [8], infrared spectroscopy [9], as well as mathematical modeling [10].

The article [5] presents the results of tests of motor oil SAE 10W-40 used in the engines of 4 groups of automobiles «Gazelle» operating under different operating conditions, namely on different types of fuel (regular gasoline and propanobutane mixture). The evaluation of motor oil resource was carried out according to the balance of acid and alkaline numbers in the samples of the operated oil taken from the engines with an average frequency of 2000 km. These indicators were determined using a titrator. The research has shown that the use of gas fuel instead of gasoline under similar other operating conditions doesn't adversely affect the reliability of motor oil and even allows to increase its operating time before the onset of the limit state. The research has also shown that the operation of an automobile in suburban conditions is characterized by stable engine loads and the absence of transient conditions. Therefore, this mode contributes to an increase in the resource of motor oil in relation to the urban cycle when working on gasoline by 2.3 times, and when working on gas – by 2 times.

The work [7] is devoted to the tribological study of contamination of various engine parts in motor oil after the engine has worked certain hours on alternative fuels derived from food waste, used oils, old plastic, etc. Based on the results of repeated tests, the authors [7] came to the conclusion that the viscosity of the lubricating oil will remain the same as when using traditional fuels, however, the number of metal particles in the motor oil has increased, and soot on the piston has also increased compared to traditional fuel. Unusual wear when using alternative fuels could be seen on the pistons, cylinder head, and intake and exhaust valves [7].

The research [9] presents the results of an experimental assessment of motor oil contamination with water with the formation of an emulsion by infrared spectroscopy. At the same time, the authors simulated mixing motor oil with water by different methods (Figure 1). According to the research results, the authors concluded that a change in the color of motor oil in itself is not a reliable means of detecting the presence of emulsions in its composition even at relatively high concentration levels, since nanoemulsions can be difficult to recognize visually.

Scientific work [10] is devoted to monitoring the condition of motor oil in diesel engines during

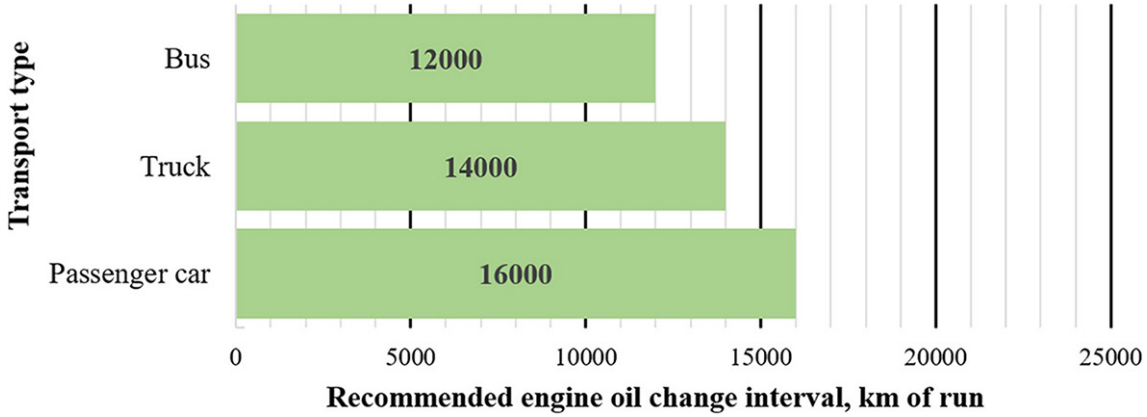

Figure 1– Recommended engine oil change interval for different types of automotive transport

operation on the example of city buses. As its authors note, often under normal conditions of operating of the internal combustion engine and compliance with the intervals between oil changes recommended by manufacturers, its physical and mechanical characteristics during operation are within acceptable limits. In the future, if the condition of the motor oil is maintained properly (which can only be confirmed by constant monitoring), the interval between oil changes can be increased. Based on this, the authors proposed a mathematical model that makes it possible to predict the optimal terms of maintenance of city buses based on monitoring the state of motor oil in diesel ICEs [10].

Scientific results

The oil change interval in kilometers of run recommended by technical documentation and regulatory documents (including Rules of technical operation of automobiles) differs for cars, trucks and buses, climatic and other operating conditions. The average value of the recommended motor oil change interval in kilometers of run for different types of automotive transport (buses, trucks and cars) [6] is shown in Figure 1. As we can see, the largest recommended motor oil change interval is for passenger cars (16,000 km of run), and the smallest is for buses (12,000 km of run).

The dependence of the recommended motor oil change interval on climatic operating conditions is clearly demonstrated in the diagram (Figure 2). The diagram rows have a gradient fill. The blue color of the row corresponds to the recommended oil change interval when operating the vehicle in a very cold climate, and the red color corresponds to a moderate climate.

Visual analysis of the diagram allows us to see a significant gap (by 1.66 times) – from 9600 km of run (for buses operated in very cold climates) to 16,000 km of run (for passenger cars operated in moderate climate) [6].

Figure 3 shows a diagram illustrating the dependence of the recommended oil change interval in the engine on the category of operating conditions of vehicles (there are 5 categories, with a lower category corresponding to lighter operating conditions, and a higher category corresponds to more severe operating conditions). In this case, the

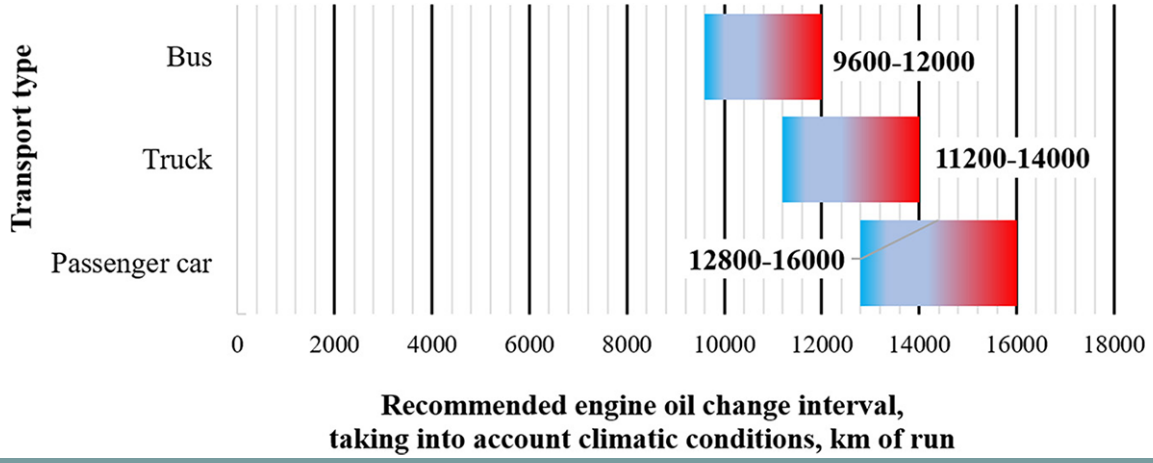

Figure 2 – Recommended motor oil change interval for vehicles of different types depending on climatic conditions of operating

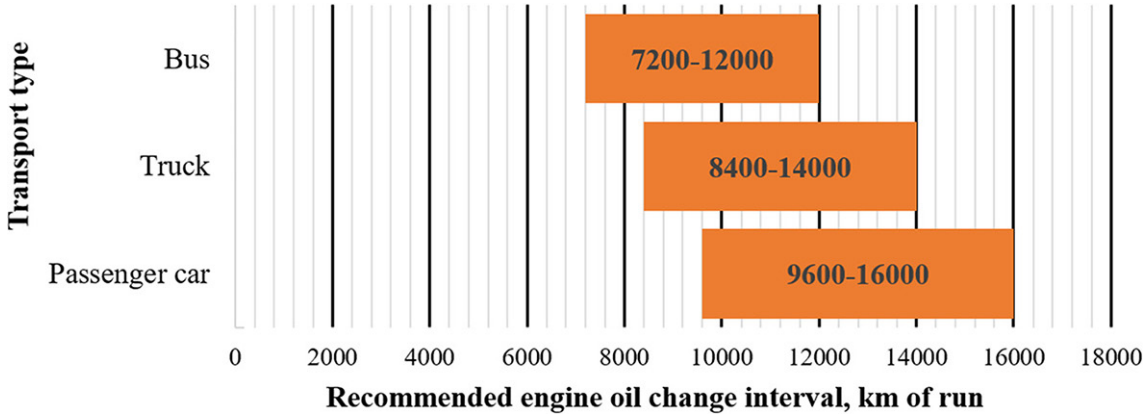

Figure 3 – Recommended motor oil change interval for vehicles of different types, depending on the category of operating conditions

gap between the recommended operating interval is even higher (2.22 times) – from 7,200 km (for buses operated in conditions corresponding to the 5th category) to 16,000 km (for cars operated in conditions corresponding to 1st category) [6].

The analysis confirmed a significant variation in recommendations for observing the oil change interval. Taking into account the analysis and the different climatic operating conditions characteristic of the Republic of Kazakhstan (cold winter and hot summer), we consider it necessary to determine the motor oil change interval not by the recommended frequency of maintenance (in kilometers or used motor-hours), but by the actual condition of the oil, determined, for example, by express control methods. The following equipment as examples of such express control tools can be cited (Figure 4):

- kit of means of express control of quality the fuel and lubricants KI-28105-GOSNITI (figure 4, a);
- mobile laboratory KI-28099 (figure 4, b);
- indicator IZH-M (figure 4, c);
- analyzer SIM-4 (figure 4, d);
- portable laboratory for the analysis of oils and fuels PLAM (figure 4, e);
- express laboratory ELT-1 (figure 4, f);
- portable laboratory «Express-VIITiN» (figure 4, g);
- portable laboratory «Kittiwake» (figure 4, h).

We have identified 13 main quality indicators that can be used to judge the suitability of engine oil for further use, as well as the condition of internal combustion engine parts. The results of the comparison of the considered means of express control by the functions performed are shown in the table 1. If the equipment supports the measurement of this indicator, there is a plus sign in the table, if not, then a minus sign.

Conclusions

Based on the results of the analysis of methods and technical means for monitoring the condition of motor oil, the following conclusions were drawn.

1) The recommended oil change interval for an internal combustion engine differs significantly depending on the type of automotive transport, climatic and road conditions. With a constant change in operating conditions, the optimal oil change interval can be either more or less than that recommended by the vehicle's operating instructions and (or) regulatory documentation.

2) For operational monitoring of the dynamics of changes in oil quality indicators in the internal

Results of comparison of equipment for express control of motor oil condition by measured parameters

Measured parameter	Name of model of equipment for express control of motor oil condition							
	KI-28105-GOSNITI	Mobile laboratory KI-28099	Indicator IZH-M	Analyzer SIM-4	Portable laboratory for the analysis of oils and fuels PLAM	Express laboratory ELT-1	portable laboratory «Express-VIITiN»	portable laboratory «Kittiwake»
relative purity	+	+	+	-	+	+	+	+
grade	+	+	-	-	-	-	-	-
percentage of water in oil	+	+	-	+	+	+	+	+
temperature	+	+	-	-	-	-	-	-
density	+	-	-	-	+	-		
kinematic viscosity	+	+	-	-	+	-	+	+
dispersing ability	-	-	-	-	+	-	-	-
oxidation (according to color photography standards)	-	-	-	-	+	-	-	-
acid number	-	-	-	-	+	+	-	+
base number	-	-	-	-	+	+	+	+
actual resin content	-	-	-	-	-	+	-	-
corrosivity	-	-	-	-	-	+	-	-
dispersing and stabilizing properties	-	-	-	-	-	-	+	-

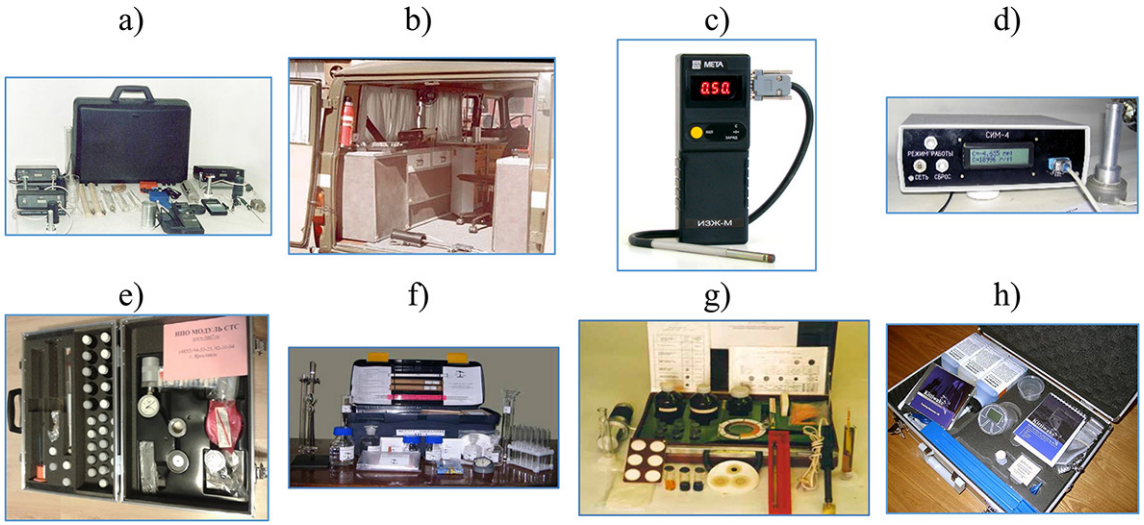

Figure 4 – Overview of equipment for express control of the condition of motor oil in the engine

combustion engines of vehicles, it is most advisable to use portable express control tools suitable for operation in the field and non-stationary conditions.

3) To conduct a comparative analysis of existing tools of express control, we selected 13 main indicators that can be used to judge the suitability of engine oil for further operation.

4) The analysis showed that the most complete and accurate measurement results are provided by the portable laboratory for the analysis of oils and fuels «PLAM», which measures 8 of the 13 considered parameters.

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Көлік техникасын пайдалану жағдайларында мотор майының жай-күйін мониторингтеудің перспективалық әдістері мен құралдарын талдау

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Аңдатпа. *Мақалада мотор майын пайдалану кезіндегі оның жай-күйін бақылау саласындағы зерттеулердің негізгі бағыттары қарастырылған. Мотор майының жағдайын бағалаудың ең перспективті әдістері анықталды. Мотор майының ресурсына әсер ететін негізгі факторлар анықталды. Көлік құралының түріне, климаттық және жол пайдалану жағдайларына байланысты мотор майын ауыстырудың ұсынылған аралықтарын салыстыру жүргізілді. ІЖҚ-дағы майдың жай-күйін жедел бағалауға арналған жабдықты салыстыру критерийлері айқындалды. Жабдықты белгілі бір критерийлер бойынша салыстырмалы бағалау нәтижелері ұсынылған.*

Кілт сөздер: *автомобиль көлігі, ішкі жану қозғалтқышы, майлау жүйесі, мотор майының мониторингі, ауыстыру аралығы, май ресурсы.*

Анализ перспективных методов и средств мониторинга состояния моторного масла в условиях эксплуатации транспортной техники

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Аннотация. *Рассмотрены основные направления исследований в области мониторинга состояния моторного масла при его эксплуатации. Описаны наиболее перспективные методы оценки состояния моторного масла. Выделены основные факторы, влияющие на ресурс моторного масла. Выполнено сравнение рекомендуемых интервалов замены моторного масла в зависимости от типа транспортного средства, климатических и дорожных условий эксплуатации. Определены критерии сравнения оборудования для экспресс-оценки состояния масла в ДВС. Представлены результаты сравнительной оценки оборудования по определенным критериям.*

Ключевые слова: *автомобильный транспорт, двигатель внутреннего сгорания, система смазки, мониторинг моторного масла, интервал замены, ресурс масла.*

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