Study of the influence of oil consumption and changes in key indicators during the operation of diesel and gas engines

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Abstract. When operating diesel engines, carburetor engines and diesel-based gas engines, carcinogenic substances contained in the lubricating oil accumulate in the exhaust gases. The content of carcinogenic components is different for diesel engines and gas engines based on diesel engines. During the operation of internal combustion engines, motor oils affect the environment with various types of pollution, as a result of waste, evaporation, leaks and spills. In these cases, the content of contaminants depends on the design, operating mode, operating conditions of the oil and its chemical composition. It has been experimentally established that the highest oil consumption is about 80-90% through the gaps in the parts of the cylinder-piston group. As the load increases, an increase in oil flow is observed. As a result of oil leaks through sealing materials, environmental pollution occurs.

1 Introduction

The issue of reducing the harmful effects of costs and leaks of motor oils requires the development of comprehensive measures. Motor oils containing carcinogenic substances have a negative impact on the environment. Reducing the impact of motor oils on internal combustion engines on the environment requires design changes and the use of fuels with lower exhaust gas content.

The composition of the atmosphere and the environment may change due to the release of various types of pollutants and exhaust gases from internal combustion engines. The composition of the exhaust gases depends on the composition of the fuel used. When operating diesel engines, carburetor engines and diesel-based gas engines, carcinogenic substances contained in the lubricating oil accumulate in the exhaust gases. The content of carcinogenic components is different for diesel engines and gas engines based on diesel engines.

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When the fuel-air mixture burns in the combustion chamber of a diesel engine, nitrogen oxide (NO) and nitrogen dioxide (NO2) are formed. As a rule, the oxide is considered as a mixture of the general formula NOx. The amount of nitrogen oxides in the exhaust gases varies depending on the operating mode of the engine and usually remains 0.1-0.2% [1-3].

In gas diesel engines, the content of mechanical impurities is less compared to diesel, the alkalinity after operation of 500 engine hours is closer to the maximum value of 2.24, the oil viscosity decreases insignificantly and after 500 engine hours is 9.3 mm2/s, the oil service life increases by an average of 25%, an increase in oil service life ensures a decrease in waste consumption, as a result of which wear on the working surface of the cylinder liner and parts of the cylinder-piston group is reduced, which serves to reduce oil consumption due to waste and as a result of leaks. This helps reduce the harmful impact on the environment.

2 Materials and methods

During the research, the influence of oil consumption during the operation of diesel engines and diesel-based gas engines was analyzed, the laws of lubrication theory, methods of experimental planning and mathematical statistics, as well as methods based on existing regulatory documents were used.

When processing experimental data, processing methods using Microsoft Office Excel application packages were used.

Research has established that dispersion analysis of the oil showed the presence of large (3-4 microns), medium (0.8-1.5 microns) and small (0.4-0.8 microns) particles; and the number of medium particles is 85-90% of the total number of particles [3]. As indicated, as the thermal stress of the engine increases, there is a slight increase in the average size of contaminant particles

In diesel and diesel-based gas engines, lubricating oil is consumed in several ways:

- penetrates into the crankcase space through the piston rings, as a result of the combustion process the oil burns out or evaporates and is released into the air with exhaust gases;
- through the valves it enters the chamber; as a result of high temperatures, varnish and sludge are created on the surface of the parts.

The amount of oil loss depends on a number of factors: the design of the engine, the type of fuel used, the amount of oil in the engine lubrication system, the thickness of the oil film, the amount of oil sprayed onto the walls of the cylinder liner.

As a result, the thermal stress of engine parts and a certain amount of oil creates varnish and carbon deposits on the surface of the cylinder-piston group parts. Modern motor oils containing functional additives exhibit high performance properties. n such cases, the likelihood of jamming of the upper compression rings may increase.

Ring jamming can occur as a result of a number of factors:

the quality of the oil used in the engine, its physical, chemical and operational properties, as well as the quality of cleaning and quantity supplied to the engine cylinder.

It has been experimentally established that the highest oil consumption is about 80-90% through the gaps in the parts of the cylinder-piston group. As the load increases, an increase in oil flow is observed.

As a result of oil leaks through sealing materials, environmental pollution occurs.

Oil consumption Q in the engine consists of its consumption for waste Q1 and for replacing used oil with fresh oil Q_2.

$$Q = Q_1 + Q_2 \quad (1)$$

With frequent changes, the Q_2 value represents a large part of the total oil consumption and reaches 60 %. For example, in some diesel engines, oil consumption per shift is 61%, and waste consumption is 39% of total oil consumption [3].

Oil waste in modern diesel and gas engines based on diesel engines is inevitable. However, thanks to improved engine design, oil waste is somewhat reduced.

The main way to reduce hourly oil consumption due to waste is to extend its service life.

For specific oil consumption Q_{sp} g/hp.h, expression (1) can be written in the following form [3]:

$$Q_{sp} = Q_w - + \frac{nG}{\tau} \tag{2}$$

Where: Q_w- oil consumption for waste in g/hp.h;

n- oil change frequency;

τ – oil service life in hours;

G – oil service life in hours.

During continuous operation of the engine oil, i.e. $\tau = \infty$

$Q_{sp} = Q_w$, those. the total oil consumption is equal only to its consumption for waste.

Oil consumption for waste depends on a number of design features of a gas engine based on a diesel engine, on the operating mode, and the main indicators of the oil. As the viscosity of the oil increases, the waste consumption decreases. For diesel engines, oil consumption due to waste is 0.03% of fuel consumption. For gas engines based on diesel engines, oil consumption due to waste is 0.02% of fuel consumption.

In diesel-based gas engines, to increase the service life of the oil, it is necessary to add a concentration of functional additives to it.

In our case, $Q_t = 0$. We denote the oil service life by τ. The oil service life under these conditions is determined by the expression:

$$\tau = \frac{G}{w} \ln \frac{A}{A - x_{re}} \tag{3}$$

When the oil works continuously, i.e. at $\tau = \infty$, the maximum impurity content will be

$$x_{re} = \text{A} = \frac{100a}{Q_w} \tag{4}$$

Hence the oil consumption for waste Q_w which provides sufficient oil refreshment for its continuous operation

$$Q_w = \frac{100\,a}{x_{re}} \tag{5}$$

During operation of a gas engine based on a diesel engine after operating for 400 engine hours, an increase in viscosity is observed as organic products accumulate.

Oil viscosity can be determined using standard methods in laboratory conditions.

Kinematic viscosity characterizes the mobility of the oil; as viscosity increases, wear of the cylinder liner and parts of the cylinder-piston group increases.

Fig. 1. The process of determining the viscosity of engine oil at temperatures of 40 and 100° C.

The kinematic viscosity of the oil (characterizing the mobility of the oil) was determined by a capillary viscometer (SST 33-2000), the operating principle of which is based on the quantitative determination of the resistance of the oil to the displacement of its layers.

With a change in temperature, the viscosity of the oil changes over a wide range, especially significantly at low temperatures. The degree of change in viscosity depends on several indicators: the hydrocarbon composition of the base oil and the presence of viscosity additives, the type of fuel used, the temperature of the oil, etc.

When determining oil viscosity in laboratory conditions, viscometers are used, or the viscosity value is determined using calculation formulas:

$$\eta = \rho \cdot К \cdot \tau, \quad Pa{\cdot}с \tag{6}$$

Where: η- oil viscosity

ρ- oil density,

К- viscometer constant,

τ- liquid flow time,

Determination of the content of mechanical impurities - foreign, mainly mineral, substances contained in oil are called mechanical impurities. Determinations of the content of mechanical impurities in oil are based on weight analysis. Fresh motor oils contain mechanical impurities in quantities of no more than 0.015-0.02%. Their content was determined according to SST 6370-2000 by filtering a sample of oil diluted with gasoline. The sediment on the filter paper was washed with gasoline, dried, weighed, and the percentage was determined.

The viscosity-temperature dependence of the oil is assessed by the viscosity index. The slower the viscosity increases with decreasing temperature, the higher the viscosity index. This property plays an important role when starting engines at low temperatures, when, due to the high viscosity of the oil, its supply to the friction units is delayed, pumping through the lubrication system is difficult, and thus conditions are created for oil starvation of bearings and other friction units. Therefore, starting wear is very significant.

In laboratory conditions, the oil temperature was determined when operating on standard liquid and gaseous fuels.

Reducing alkalinity as a result of neutralization of acidic compounds and, above all, combustion products of sulfur fuel is a very important process that determines the intensity of wear and the amount of carbon deposits in the engine [3-9].

When the engine is operated without changing the oil for 240 hours, the alkalinity reserve of some additives is almost completely used up. The rapid activation of the active part of the additive leads to a rapid drop in neutralizing and detergent properties, which in turn leads to a reduction in the oil change period in the engine [3-9].

Studying the kinetics of changes in oil alkalinity is considered the simplest way to study the kinetics of additive response. The rate of consumption of the alkaline additive depends on the content of acidic substances in the fuel combustion products.

According to the work of Morozov A.G., Ortsiomova O.M. [3], the rate of change in alkalinity K is determined from the formula:

$$К = 0{,}35y\ FS, (\text{in mg KOH/g}) \tag{7}$$

Where: F- fuel consumption, kg/h; S - sulfur content in fuel, %;

The expression for the speed of operation of the additive can be written as:

$$\frac{dC}{dt} = -KC, \tag{8}$$

Where: C is alkalinity, K is the response rate constant.

By integrating this expression, you can obtain the simplest (without taking into account waste and adding oil) dependence of oil alkalinity on time [3-9]:

$$C = C_0 e^{-kt}, \quad (9)$$

Where: C_0 - initial oil alkalinity.

The base number was determined by potentiometric titration according to SST 11362-2000. The total number was taken to be the amount of potassium hydroxy in milligrams, equivalent to the amount of hydrochloric acid consumed to neutralize all the main compounds contained in 1 g of the analyzed oil.

Fig. 2. Determination of oil alkalinity in laboratory conditions.

In the technical specifications for modern oils used in tractor diesel engines, the following values of alkali numbers are established: for oils of group B_2, no less than 3.5 mg KOH per 1 g of oil, for group G_2, no less than 6 mgkон/g of oil.

The base number of motor oil characterizes the ability of the lubricant to neutralize harmful acids. Due to the nature of its chemical formula, diesel fuel releases more acids when burned than gasoline or gaseous fuels.

Consequently, for engines running on diesel fuel, the TBN indicator will be maximum (approximately 10 mg). Gasoline installations are less demanding. Therefore, manufacturers a priori put less mgKOH/g into the oil (about 2 mg).

3 Results and discussion

One of the main factors affecting the service life of motor oil is kinematic viscosity. Based on the research results, comparative changes in the kinematic viscosity of oil in diesel engines and gas engines based on diesel engines were determined, depending on the duration of operation.

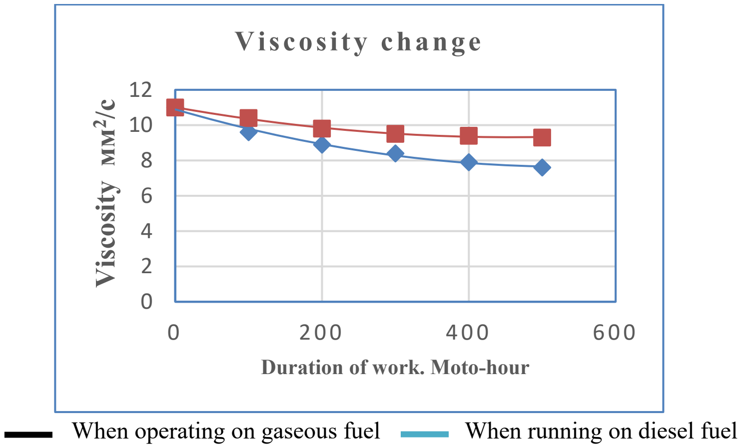

Fig. 3. Change in kinematic viscosity of oil when the engine runs on diesel and gaseous fuel.

Based on the research results, comparative changes in the kinematic viscosity of oil in diesel engines and gas engines based on diesel engines were determined, depending on the duration of operation.

The graph shows that in the initial period of operation of an engine running on gaseous fuel, there is a decrease in viscosity (from 11.2 to 9.8 mm2/s), and only after 400 hours of operation the viscosity remains unchanged. When operating on diesel fuel, a sharp decrease in oil viscosity is observed. Perhaps this fact is due to diesel fuel getting into the engine crankcas.

The base number of gas engine oil is also 1.5 times higher than in a sample of oil running on diesel fuel.

The alkaline number in samples of used oils varies from 2.24 to 1.4, which indicates the emergency condition of the used oil. The results of analyzes of the alkaline number of the studied motor oils show that when the engine is running on gaseous fuel it decreased on average from 6.0 to 2.24 mg KOH/g, and when running on diesel fuel from 6.0 to 1.4 mg KOH/g g i.e. below the permissible level.

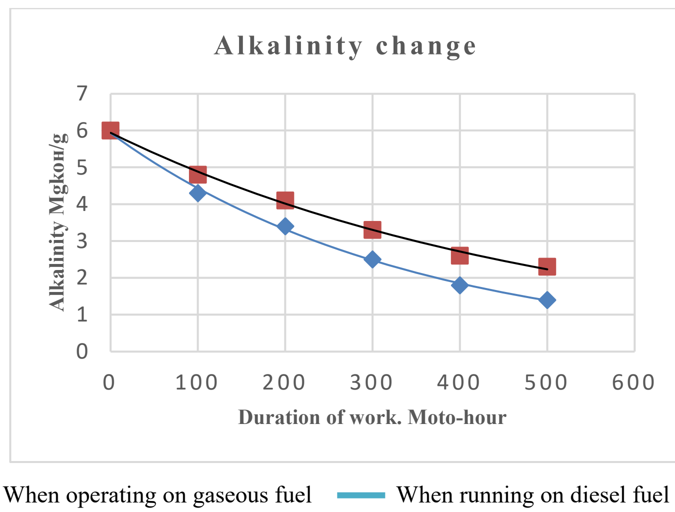

Fig. 4. Change in alkalinity of diesel and gas diesel engine oils.

Table 1. Physico-chemical indicators of used diesel engine oils.

Characteristics of oils	**engine operating time, Moto-hour**					
	0	**100**	**200**	**300**	**400**	**500**
Kinematic viscosity, at 100^0 C.	11.2	9.6	8.9	8.4	7.9	7.6
Oil alkalinity мgKOH/g	6.0	4.3	3.4	2.5	1.8	1.4
Content of mechanical impurities, %	0.015	0.020	0.025	0.029	0.034	0.038

Table 2. Physico-chemical indicators of used gas-diesel motor oils.

Characteristics of oils	**engine operating time, Moto-hour**					
	0	**100**	**200**	**300**	**400**	**500**
Kinematic viscosity, at 100^0 C.	11.2	10.4	9.8	9.5	9.4	9.3
Oil alkalinity мgKOH/g	6.0	4.8	4.1	3.3	2.6	2.24
Content of mechanical impurities, %	0.015	0.018	0.020	0.023	0.026	0.028

4 Conclusions

According to the research results, we can say that in gas diesel engines, the content of mechanical impurities is less compared to diesel, the alkalinity after operation of 500 engine hours is closer to the maximum value of 2.24, the oil viscosity decreases insignificantly and after 500 engine hours is 9.3 mm2 /s, the oil service life increases by an average of 25%, an increase in oil service life ensures a decrease in waste consumption, as a result of which wear on the working surface of the cylinder liner and parts of the cylinder-piston group decreases. which serves to reduce consumption due to waste and as a result of leaks. What helps reduce the harmful impact on the environment. During the operation of internal combustion engines, motor oils affect the environment with various types of pollution, as a result of waste, evaporation, leaks and spills. In these cases, the content of contaminants depends on the design, operating mode, operating conditions of the oil and its chemical composition.

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