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TECHNOLOGY OF OBTAINING MIXED ALTERNATIVE FUEL BASED ON ORGANIC SUBSTANCES FOR MINING TECHNOLOGICAL TRANSPORT ENGINES

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Abstract:
In connection with the increase in the price of fuel based on hydrocarbons, the search and use of alternative types of fuel for machines in the mining and oil production industry is quite relevant today. Most of the existing alternative fuels by themselves cannot be considered as ready-to-use motor fuels. One of the ways to solve this problem is to use their mixtures with commercial fuels in certain ratios. This work deals with the development and research of the main characteristics of the mixer for obtaining mixed fuels based on diesel fuel and soybean oil, as well as the results of the study of the physical and operational properties of the obtained mixtures of different volume ratios of diesel fuel and soybean oil. The process of obtaining a mixed alternative fuel based on diesel fuel and soybean oil was implemented on a developed installation consisting of a mixer, the design of which is protected by a patent of Ukraine, and a gear pump. The study of the characteristics of the mixer as part of the installation showed that at a temperature of the components of the alternative fuel of 20°C, with a loss of full pressure on the mixer Δp ≈ (60-65) kPa, the volume consumption of soybean oil reached 10.7.10-6 m3/s. The time of preparation of the fuel mixture in the amount of 195 liters with a content of soybean oil of 10% ranged from 30 to 33 minutes. As research has shown, mixing soybean oil with diesel fuel in the amount of 5-50% vol. provides an improvement in viscosity-temperature properties and makes it possible to use such mixtures in diesel engines without changes in the design of the power supply system and regulation of fuel equipment, which characterizes soybean oil as a promising additive to diesel fuels to improve their technical and operational performance.

Key words: *technology, alternative fuel, equipment, mixer, improvement, operational properties of fuels*

INTRODUCTION

Currently, in the field of alternative types of fuel, there is a constant increase in the volume of their production. In Europe and the world, increasingly strict requirements of the environmental standard are being introduced (Euro 6, from 2025 Euro 7), the application of which requires cars and motor fuels to increase their environmental safety. However, most alternative fuels by themselves cannot be considered ready-to-use motor fuels. This is due to the fact that the operational and environmental properties of most alternative fuels do not correspond to the properties of commercial fuels. Solving this problem is possible in two main ways:

1) improving the properties of alternative fuels due to their refinement and purification;
2) the use of mixtures of alternative fuels with commercial fuels in certain ratios that will not harm either the engine or the environment.

LITERATURE REVIEW

Biodiesel fuel, as a rule, is obtained from oil crops and used as an additive to traditional diesel fuel, and in some cases as pure biofuel.

Due to the limited and exhaustive raw material base of hydrocarbons, biofuel is the fuel of the future, in particular for mining technological transport engines. As a rule, it is a cleaner type of fuel, unlike commercial fuels, biofuels are made from renewable resources, and therefore biofuels are very profitable for countries that are forced to import oil.

In work [1], an analysis of the main types of alternative fuel for diesel internal combustion engines (ICE) was performed, their main indicators were studied, and the main physicochemical indicators of the most common types of biodiesels were evaluated and the necessary conditions for their use in ICE were described. However, from the conducted studies, it is not possible to assess the impact of (Soybean Methyl Ester) SME additives on the nature and regularity of changes in the main technical and operational indicators of the obtained biodiesel fuel.

The work [2] is devoted to the analysis of the physicochemical and operational properties of biodiesel fuel based on ethyl esters of fatty acids of castor oil and mixed biodiesel fuels with different percentages of ethyl esters. A comparative analysis of biodiesel fuel samples based on methyl and ethyl esters of fatty acids of rapeseed and castor oil was carried out. As a result of the study, the use of castor oil for the production of biodiesel fuel, namely for the full or partial replacement of traditional petroleum diesel fuel, is substantiated.

The study of the effect of biodiesel fuel on the toxicity of diesel fuel was carried out in [3]. The authors proposed a number of measures to improve the environmental performance of a diesel engine and investigated their impact on power and efficiency. Optimizing the fuel injection advance angle and optimizing the minimum value of the excess air coefficient were the most promising measures to improve the environmental performance of the internal combustion engine, as a result of which nitrogen dioxide emissions decreased by 63%, and its smoke level decreased by 78%.

In [4], the main fuel-lubricant properties of biodiesel in comparison with conventional diesel fuel, its influence on engine power are considered. The authors also analyzed the fuel consumption and thermal efficiency of biodiesel, in comparison with conventional diesel fuel, and investigated the emission indicators of biodiesel and diesel fuel. Based on the results of research, it was established that when using biodiesel fuel in engines, nitrogen oxide emissions increase, but they can be controlled by making certain decisions, such as adding a methane improver, injection delays, exhaust gas recirculation, etc.

Large-scale studies of biodiesel fuel were carried out by the authors of the work [5]. They established that the operation of a diesel engine on biodiesel fuel with a higher density and kinematic viscosity is accompanied by an increase in maximum power and torque, as well as an increase in fuel consumption. At the same time, the concentration of nitrogen oxides in the exhaust gases and smoke also increases.

The paper [6] considers the possibility of using fusel alcohol as an additive to motor diesel fuel. The results of experimental studies of diesel engines operating on a mixture of diesel fuel and fusel alcohol are presented. Based on the results of the research, the fuel and environmental indicators of engines running on a mixture of diesel fuel and fusel alcohol have been improved. However, fusel alcohol also have a negative impact on the elements of the engine power system, as it contain up to 8% water, which is unacceptable for diesel fuel.

The authors [7] study the biodiesel production process, in particular the impact of capital investments on the cost of fuel production. The results show that the main component of the cost of biodiesel fuel is the price of raw materials. And, therefore, by reducing the cost of production of raw materials, it is possible to achieve the economic efficiency of using soybean oil for the production of biodiesel fuel.

Similar studies of the production cost of cellulosic ethanol, developed and tested by the University of Florida in laboratory, pilot and demonstration scales, were carried out in [8]. The minimum selling price of ethanol ranged from 50.38 to 62.72 USA cents/l. The main contribution to the cost of production was made by raw materials and capital costs, which were from 23-28% to 40-49%, respectively. These findings suggest that future efforts to improve the economic feasibility of the cellulosic ethanol process should focus on optimization to obtain the highest ethanol yield.

An important factor in the use of alternative fuels for diesel engines in the mining industry is the harmful emissions that pollute the air and soil. In works [10, 11, 12, 13, 14], scientists performed a number of mathematical and experimental studies related to the influence of alternative fuels on the state of atmospheric air and soils.

For example, work [10] proposes to improve the environment, preserve traditional fuel and energy resources, and diversify sources of energy supply through the introduction of torrefaction technology due to the use of biomass energy.

In [11], an analysis of biological resources for the production of biofuel was carried out. Based on the results of research, it was found that the use of alternative fuels solves the problems of environmental pollution and leads to a decrease in the concentration of harmful components in the exhaust gases of internal combustion engines.

Since the environmental requirements for the composition of ICE waste gases are increasing, more and more attention is being focused on the problems of reducing the influence of these factors on the composition of ICE waste gases every year. The significance and acuteness of this problem are growing due to the annual increase in emissions by motor vehicles of substances that pollute the atmosphere and soil (on average, by 3-5%) [12].

Based on the results of mathematical modeling in [13], a model of distribution of heavy metals in soils was obtained. When the surface concentrations increase, the penetration depth of heavy metals increases, which is explained by the increase in the driving force of the diffusion process.

The composition of the soil and the type of components, established by the authors [14], have a significant influence on the distribution of heavy metals in the soil. According to research results, manganese migrates most easily in all types of soil, and forest soils are the most resistant to the penetration of heavy metals. However, the authors did not establish the patterns of penetration of heavy metals, and therefore did not propose a methodology for predicting their migration.

The thermal state of the engine has a significant influence on the spread of harmful components emitted with the exhaust gases of the internal combustion engine in the soil. The authors of works [15, 16] proposed measures to accelerate engine warm-up after start-up and studied the dynamics of reducing harmful emissions. But the system proposed in [15] is somewhat complicated, and the suburban traffic cycles chosen in [16] significantly underestimate the real emissions of harmful components. For example, in [17], to improve the environmental performance of diesel engines, it is proposed to use a hydrogen-diesel mixture as fuel, which reduces harmful emissions by 30%.

High environmental performance of a diesel engine was obtained in work [18] when converting its power system to biogas, which as a result allows reducing its toxicity by 65%.

In work [19], it is proposed to reduce the negative impact of engines on the environment by using innovative fuel production technologies, which ensures a reduction in toxicity by 15-20%.

The use of mineral fuels for jet engines [20] has a positive effect on the environmental indicators of their operation and reduces the level of environmental pollution by 25-30%.

Also, the rational choice of the type of fuel, which is indicated in [21], plays an important role in reducing emissions of harmful components of engines into the environment, this will contribute to reducing the toxicity of the engine by 5-10%.

The authors [22] propose to reduce the negative impact of road transport on cities by improving the routes of urban public transport.

In work [23] emissions of harmful components were studied not only from fuels, but also from car lubricants. The shortcoming of this work is that the authors of the study limited themselves only to freight vehicles.

The issue of changes in the concentration of harmful components on the soil depending on the composition of the mixture and the structure of the engines was considered in [24]. But the authors did not take into account all the design features of modern automobile engines that affect the concentration of toxic components in the soil.

As you can see, a lot of attention of scientists is directed to the research of biodiesel based on rapeseed. Of the plants suitable for the production of biofuel, wheat and sunflower have the largest sown area in Ukraine. Spring rape and winter rape, soybeans, corn and sugar beet are also grown. Almost all of these plants, except soybeans and wheat, pose a danger to the soil. And, therefore, based on the above, soybeans are more promising for obtaining biodiesel fuel.

THE PURPOSE AND TASKS OF RESEARCH

Therefore, in order to improve the operational and environmental properties of commercial fuels and the industrial scale of production of alternative mixed biodiesel fuels with SME, it is necessary to develop a technological scheme using special equipment and to investigate the main physical and operational indicators of the obtained fuel mixtures. To achieve the purpose, the following main tasks were formulated:

- development of an installation for obtaining mixtures of diesel fuel and SME in the required volume ratio using a mixer manufactured according to the authors' patent;
- investigation of the operating parameters of the installation for obtaining mixed fuels of the required volumetric composition;
- research of physic-chemical and operational indicators of diesel fuel and SME mixtures.

METHODOLOGY OF RESEARCH

The parameters of the mixer for the experimental installation, the main physical and operational parameters of diesel fuel and SME mixtures (cetane number, density, kinematic viscosity) were studied experimentally. The methods of least squares and mathematical statistics were used during experimental research and processing of results.

At the same time, the author team actively used the design-thinking methodology mentioned in the work [9] as a creative way of solving the problem, which in modern conditions is increasingly becoming an effective tool for improvements, including processes related to technical and technological transformations.

Development of an installation for obtaining diesel fuel mixtures with SME

For mixing SME with diesel fuel in production conditions, a mixer (Figure 1 and 2) was developed and manufactured according to the author's patent [10]. Its principle of operation is as follows: diesel fuel enters through nozzle 1 to the housing of the mixer 2 and causes rotation of the rotor 5, and the resulting fuel mixture is discharged from the mixer through nozzle 3 (Fig. 1).

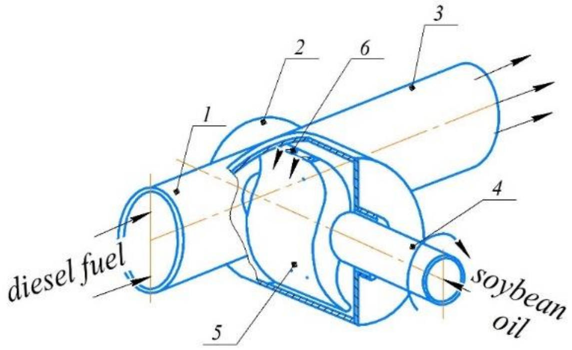

Fig. 1 Mixer for motor fuels according to the author's patent: 1 - nozzle for fuel supply; 2 - body; 3 - nozzle for removing the fuel mixture; 4 - pipe for supplying SME; 5 - rotor; 6 – openings
Source: [25].

The inner diameter of nozzles 1, 3 and body 2 are 17, 21 mm and 68 mm, respectively. During the rotation of the rotor, SME is sucked under the action of centrifugal forces through the nozzle 4 with a diameter of 12 mm to the inner axial cavity of the rotor 5. The height of the rotor blade is 32 mm, the axial length of the blade is 45 mm. During the rotation of the rotor, SME spraying is carried out through twenty radial holes 6 (ten on each blade) in the rotor with a diameter of 1.5 mm, connected to the inner axial cavity of the rotor. For the process of obtaining mixtures of commercial diesel fuels with SME in the conditions of an operating motor vehicle enterprise and for the study of the characteristics of the mixer, an installation was developed and assembled, the diagram of which is shown in Figure 2.

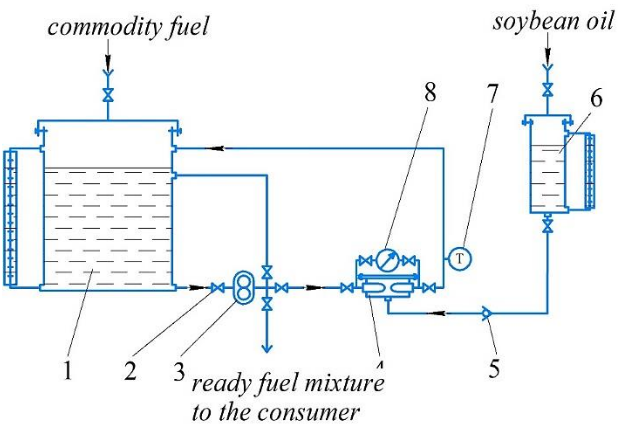

Fig. 2 Scheme of the installation for obtaining mixtures of commercial fuels with SME in production conditions: 1 - vessel for commodity fuel; 2 - valves; 3 - gear pump; 4 - motor fuel mixer; 5 - return valve; 6 - measuring cylinder for SME; 7 - thermoelectric thermometer; 8 - differential manometer

The process of obtaining alternative fuel mixtures containing SME is implemented in the following way. Vessel 1 (Figure 2) is filled with commercial fuel so that the volume of the resulting fuel mixture with a predetermined percentage of SME does not exceed the capacity of vessel 1- 200 liters. In proportion to the amount of commercial fuel, a corresponding amount of SME is poured into vessel 6 with a volume of 35 liters. After that, pump 3 is turned on, which supplies fuel from vessel 1 to mixer 4, and then the resulting mixture enters vessel 1. Circulation of the fuel mixture through the mixer 4 stops after emptying the vessel 6, and the resulting fuel mixture is supplied to the consumer by the pump 3.

The installation uses a mixer according to the author's patent [25], the characteristics of which are given above, and a gear pump of the NMSHF 2-40-1.6/4B-13 model. The maximum pump delivery is 1.6 m^3/h at a maximum overpressure of 0.4 MPa, and the nominal power of its drive is 1.1 kW.

RESULTS OF RESEARCH AND DISCUSSION

Based on the results of studies of the main physical and operational indicators of fuel mixtures of diesel fuel and SME produced at the specified installation, experimental dependences of the cetane number change on the percentage volume content of SME in it were obtained (Figure 3).

According to Fig. 3 cetane number with the SME additive increases, and this will lead to easier starting of the diesel engine, increase the maximum fuel combustion pressure. But a significant increase in the cetane number will lead to an increase in specific fuel consumption, toxicity and smoke of exhaust gases, and therefore, according to this indicator, the optimal content of SME in diesel fuel is up to 60% by volume.

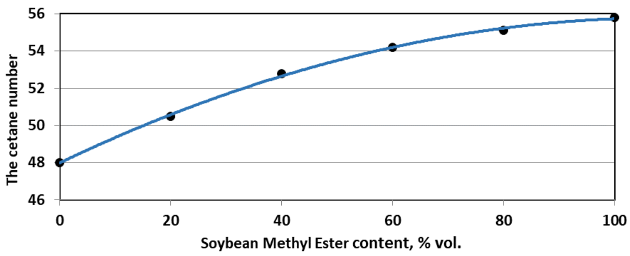

Fig. 3 Graphical dependence of the change in the cetane number of diesel fuel on the content of SME, % vol.

Fuel pumping, trouble-free operation of the high-pressure fuel pump, wear of precision vapors, continuity of fuel supply to the cylinders, fineness of atomization and completeness of combustion, its consumption and the composition of exhaust gases largely depend on the viscosity and density of the fuel. In Figures 4 and 5 show the obtained experimental dependences of the change in density and viscosity of diesel fuel on the percentage volume content of SME in it.

The density of fuel for high-speed diesel engines should be within 820-860 kg/m^3, and the viscosity for summer diesel fuel within (3.0...6.0).10-6 m^2/s. According to Figure 4 SME additives to diesel fuel significantly affect the density of the latter, and therefore, according to this indicator, adding SME to the mixture is possible up to 58% vol.

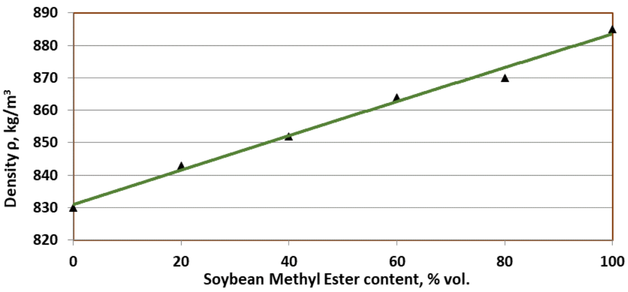

Fig. 4 Graphic dependence of the change in the density of diesel fuel from SME content, % vol.

For diesel fuels, the kinematic viscosity is determined at a temperature of 20°C. Fuel with a very high viscosity can cause interruptions in its supply to the pump due to resistance to flow through the fuel system through filters and nozzle holes. When the fuel viscosity decreases, the lubrication of the precision pairs of the high-pressure fuel pump deteriorates, and fuel leakage is observed due to leaks between the plunger and the sleeve.

As can be seen from Fig. 5 SME additives to diesel fuel lead to an increase in kinematic viscosity, which lubricates precision pairs and elements of the power system. According to this indicator, the addition of SME to diesel fuel is possible up to 100% vol.

The content and nature of sulfur compounds has a decisive influence on the corrosive aggressiveness of diesel fuels. It has been established that the overall operation of engine parts is almost directly proportional to the sulfur content in diesel fuel. For example, when the sulfur content is increased from 0.2 wt. %. up to 0.6 wt. % activation of cylinder liners and piston rings increases by approximately 5-20%, and when the sulfur content increases to 1% by mass. the operation of these parts increases by 1.5 times. The total content of sulfur in diesel fuel should not exceed 0.05% by weight.

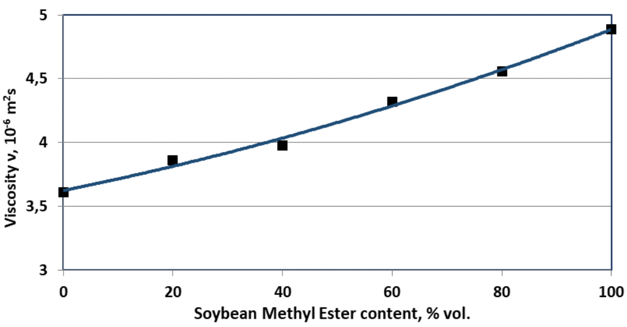

Fig. 5 Graphical dependence of the change in the viscosity of diesel fuel from SME content, % vol.

According to the research results of Figure 6, with an increase in the content of SME in diesel fuel leads to a decrease in the sulfur content to 0.02%, which significantly improves the quality of diesel fuel and significantly reduces its corrosion activity to the parts of the power supply system and cylinder-piston group.

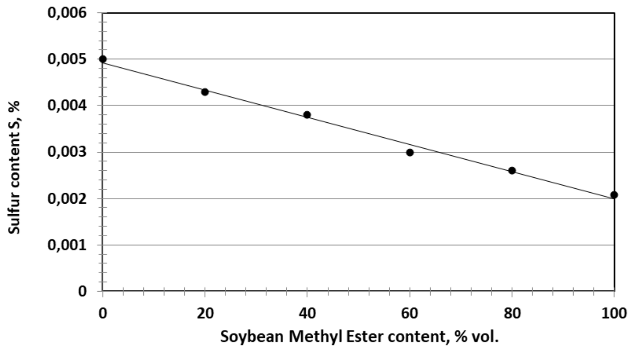

Fig. 6 Graphical dependence of the change in the sulfur content in diesel fuel from the SME content, % vol.

The heat of fuel combustion affects its consumption and engine power. The more heat obtained during fuel combustion, the more power can be extracted from the engine, the lower the specific fuel consumption. Hydrocarbon fuels differ little in calorific value, their lower calorific value ranges from 41,000 to 44,000 kJ/kg.

According to the results of the study of the influence of SME content in diesel fuel on the lower heat of combustion of fuel (Figure 7) it is established that the increase in the volume share of SMEs leads to a decrease in this indicator.

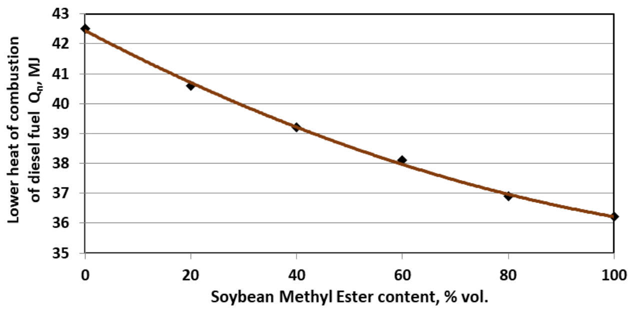

Fig. 7 Graphical dependence of the change in the lower heat of combustion of diesel fuel on the content of SME, % vol.

And, therefore, for optimal operation of the engine, ensuring its economy based on the indicator of lower combustion heat, it is recommended to add SME no more than 40% vol.

CONCLUSION

The process of obtaining a mixed alternative fuel based on diesel fuel and soybean oil was implemented on a developed installation consisting of a mixer, the design of which is protected by a patent of Ukraine, and a gear pump model NMSHF 2-40-1.6/4B-13.

The study of the characteristics of the mixer as part of the installation showed that at a temperature of the components of the alternative fuel of 20°C, with a loss of full pressure on the mixer Δp ≈ (60-65) kPa, the volume consumption of soybean oil reached 10.7.10-6 m^3/s. The time of preparation of the fuel mixture in the amount of 195 liters with a content of soybean oil of 10% ranged from 30 to 33 minutes.

According to the results of the obtained studies, the SME additive to diesel fuel is up to 60% vol. provides an increase in its cetane number up to 11%, improvement of viscosity-temperature properties and makes it possible to use such mixtures in diesel engines without changes in the design of the power supply system and regulation of fuel equipment, which characterizes SME as a promising alternative fuel for internal combustion engines.

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