INFLUENCE OF MAGNETIC FIELD ON THE ANTIWEAR PROPERTIES OF DIESEL FUELS REFORMULATED BY BIOCOMPONENTS

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Abstract

The article discusses the issue of antiwear properties of traditional and alternative diesel fuels. The main goal of this work was the theoretical and experimental studies on the effect of alternative biodiesel fuels (on a plant basis) on the change in the antiwear properties of traditional diesel fuels. Also, the goal was to study the effect of the magnetic field on the antiwear properties of diesel and alternative diesel fuels. Experimental studies have been conducted for the antiwear properties of traditional and alternative diesel fuels based on biocomponents obtained from rye oil.

Keywords: antiwear properties, diesel fuel, biocomponent, rye oil, magnetic field, friction, wear.

Introduction and research objectives. The failures of certain systems may occur due to an increase in the level of wear of parts during the operation of diesel equipment. The common experience on the operational reliability of fuel systems of diesel engines shows that up to 50 % of diesel engine failures, from 20 to 40 % of hydraulic and almost 10 % of fuel system failures occur as a result of a decrease in the operational properties of fuels. And the service life of pumps and other units is reduced by 6-7 times for this reason [2].

Increasing of the durability, reliability and economy of diesel engines is a complex problem. The solution is achieved at all stages of design, production and operation of equipment. An important condition is the improvement of the operational properties of diesel fuel for the reliability and durability of the engine design.

High requirements are required for the properties of fuel and lubricant materials due to the fact that aviation and ground equipment is constantly being improved and it is necessary to ensure its durability, reliability and economy.

The characteristics of diesel engines can be improved by using the physical effects. In particular, by the influence of electromagnetic pulses of a certain form on the fuel entering to the diesel engine.

There are enough works (for example, [3]) that were conducted on the study of direct influence of the electromagnetic fields to the properties of various liquids. Such devices are especially popular for use in the petrochemical and energy industries. At the same time, there is a decrease in the degree of pollution of combustion chambers and pipelines, as well as a decrease in the smoke level of exhaust gases.

Improving the antiwear properties of fuels for diesel engines is one of the main factors for ensuring the reliability of diesel equipment and its friction components.

There is a need to improve the tribochemical properties of traditional and alternative diesel fuels to ensure current requirements for diesel fuels.

The antiwear properties of diesel fuels determine the reliability and service life of engine fuel units, particularly their friction pairs. These friction pairs work in the modes of rolling friction, sliding friction and combined friction under different loads, temperatures, pressure, relative movement speed under conditions of liquid and boundary lubrication [8].

The lubricating properties of fuels are very important and depend on their chemical composition, viscosity, thermooxidative stability, the content of mechanical impurities, as well as the presence of surfactants. It is known that at high specific loads, semi-liquid friction is usually observed, in which the friction surfaces aren’t completely separated by the fuel [3].

In the case of semi-liquid friction, the antiwear properties of diesel engine fuels are determined by:

1) fuel viscosity, which ensures the hydrodynamic effect of separation of friction surfaces by a layer of liquid;

2) the presence of surfactants in the fuel, which form a strength absorption layer on the friction surface, which separates the friction surfaces, that reducing the friction coefficient and wear of parts.

Rapeseed and rye are the most popular crops for the production of biofuels in Ukraine. Rapeseed is one of the most suitable for the production of alternative fuels according to its chemical composition and technical characteristics. However, it is a picky culture and requires constant fertilization, and also significantly depletes the soil. It is not recommended to add the pure rapeseed oil to diesel fuel, because it has a high viscosity, low freezing point, contains water and organic acids, which are unfavorable factors for using pure rapeseed oil as a fuel.

Rye has a high profitability of production. Rye oil is quite effective and doesn't reduce the quality and performance of diesel engines. Rye seeds contain 40 to 50 % oil, which provides an oil yield of approximately 1250 l/ha. Another advantage of this culture is the possibility of using meal (a by-product) as feed for farm animals and poultry.

The antiwear properties were investigated for diesel fuel, fatty acid ethyl ester of rice oil and mixtures of diesel with plant biocomponents during an experiment. Biocomponents were represented by a mixture of methyl esters of fatty acids of rye oil and met the requirements of EN 14214 [10], which are modified for use as fuel components for diesel engines.

We used the complex for study the tribological characteristics of fuel and lubricant materials, developed by the authors [6,7], to study the state of the friction surfaces and the friction coefficient. Taking into account the technical conditions of the complex, it is possible to conduct photo and video recording of surface transformations in dynamic mode based on the technical conditions of the complex (Fig. 1).

The device used to study friction surfaces in constant uniform and non-uniform magnetic fields consists of: a rotation drive in the form of an electric motor; the stator of the strain gauge beam, on which the working sample is fixed; a disk with a counterbody, to which the working sample is pressed using a strain gauge beam, and its strain gauge is connected to a device that registers a bed, a microscope, a camera, an acoustic microphone, a load spring, and also contains a computer for displaying the frequency response and a computer for displaying the surface of the working sample.

Also, two magnets are additionally installed, one facing the other in such an order that allows changing the location of the poles, parallel to the disk with the counterbody and the working environment, which create a constant uniform and non-uniform magnetic field that affects the working environment. It makes it possible to carry out additional research.

Fig. 1. Equipment for research of materials on friction and wear during reverse movement: 1 – an independent power source for creating a magnetic field in the friction zone, 2 – ammeter for recording the magnetic field, 3 – ammeter for recording the current in the friction zone, 4 – chopper, 5 – magnetic circuit, 6 – inductor, 7 – power source, 8 – an oscilloscope for recording the parameters of the electric current in the magnetic circuit, 9 – loading, 10 – friction knot, 11 – capacity for the working medium.

The studies were carried out according to the "finger-plane" friction scheme, the samples material SHX15 is steel 45 (hardened to HRC 52), $\vartheta = 0.20$; $P = 5$ N, $\nu = 1$ Hz. Dimensions of the sample finger: diameter – 4 mm, length – 33.5 mm. The assessment was carried out for the samples wear with profilography of wear spots and obtaining the amount of volumetric wear according to the method [9]. Diesel and biodiesel fuels were used for the research that modified with ethyl esters of fatty acids of castor oil, as well as diesel and biodiesel fuel modified with ethyl esters of fatty acids of rye oil treated with a magnetic field.

An equipment [11] was used for the research of friction materials. It consists of: an electric motor, a bed, the microscope Metam P-1 "LOMO", the camera "Quick 5 Cam Express", a stator of a strain gauge beam, which contains a load spring and an acoustic microphone and a working sample is attached, a disk with a counterbody, a computer for displaying the frequency characteristics and a computer for displaying the surface of the working sample.

The study was carried out on the friction machine in environments according to the Tables 1, 2.

Table 1

Matrix for the study of antiwear properties of diesel and biodiesel fuels modified with ethyl esters of fatty acids of rye oil

Sample No.	Content of ester in the fuel volume, %	Sample working time, *t*, [hours]
1	10	20
2	20	20
3	10	20
4	20	20
5	10	60
6	20	60
7	10	60
8	20	60

Table 2

Matrix for the study of antiwear properties of diesel and biodiesel fuels modified with methyl esters of fatty acids of rye oil treated by a magnetic field (with constant magnetic field action)

Sample No.	Induction of magnetic field, Tl [Tl]	Content of ester in the fuel volume, %	Sample working time, *t*, [hours]
1	0.1	10	20
2	0.3	10	60
3	0.1	20	60
4	0.3	20	20
5	0.1	10	60
6	0.3	10	20
7	0.1	20	20
8	0.3	20	60

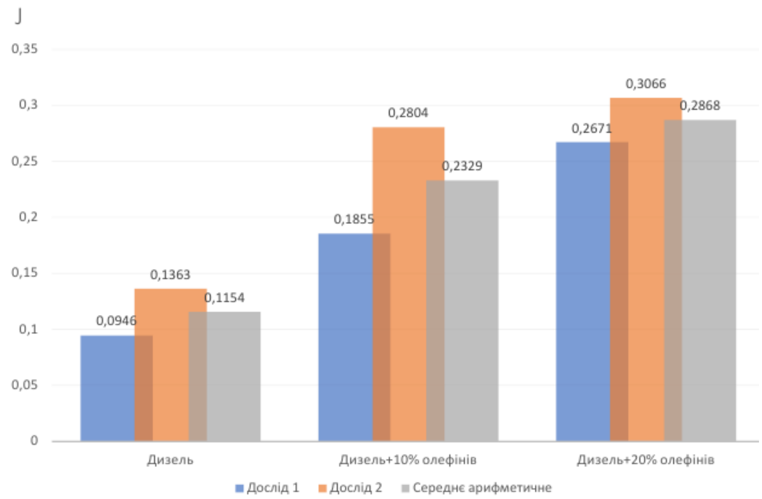


Fig. 2. Alloy wear SHX15 is steel 45 (hardened) depending on % of methyl ester content in diesel fuel, sample load P = 0.5 kg, speed ʋ = 0.2 m/s.

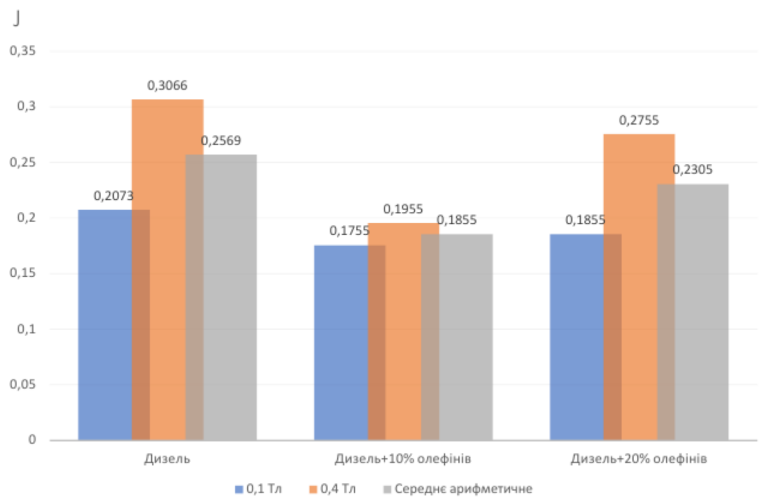
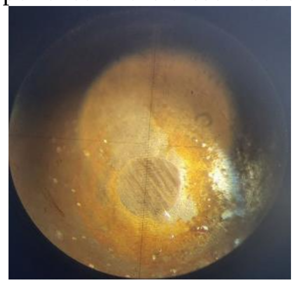


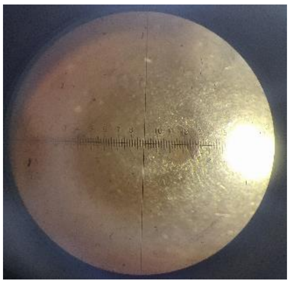
Fig. 3. Alloy wear SHX15 is steel 45 (hardened) depending on % of methyl ester content and induction of magnetic field in diesel fuel, sample load P = 0.5 kg, speed ʋ = 0.2 m/s.

Fig. 4 and Fig. 5 show microphotographs of the surfaces of samples worked in diesel fuel and mixed fuels without the action of a magnetic field and in a magnetic field.

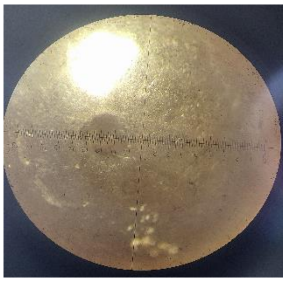
Wear of the ball-shaped surface in these studies is distinguished by the area of the obtained contact. Work experience in the diesel fuel at Fig. 4a is characterized by the formation of a film of significant thickness parallel to the participation of abrasive wear, which provoked the combined removal of the worn material of the sample. The appearance of the contact spot, its diameter is almost one and a half times larger than that of diesel fuel + 20 % methyl esters.



a) Sample in diesel fuel



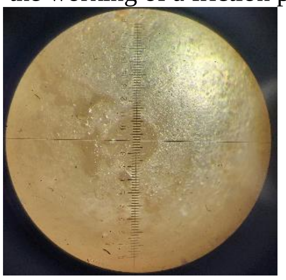
b) Sample in diesel fuel + 10 % of methyl esters



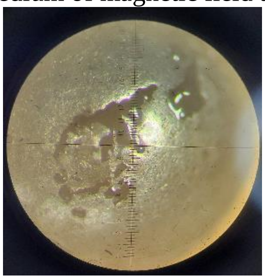
c) Sample in diesel fuel + 20 % of methyl esters

Fig. 4. Photomicrographs of the wear contact spot on an alloy sample SHX15 depending on % of methyl ester content in diesel fuel, sample load P = 0.5 kg, speed υ = 0.2 m/s.

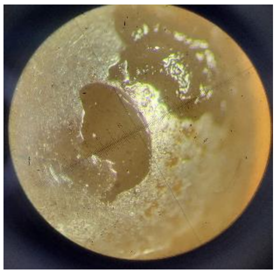
The regularity of increasing wear can be traced with increasing of the magnetic field strength due to contact, under the working of a friction pair in the medium of magnetic field and ester.



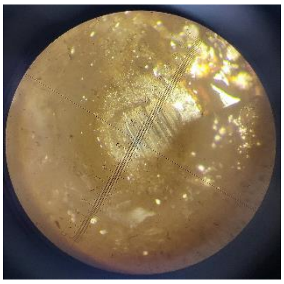
Diesel fuel + magnetic field 0.1Tl



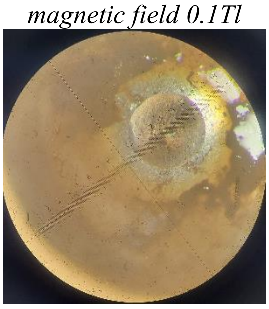
Diesel fuel + 10 % of methyl ester magnetic field 0.1Tl



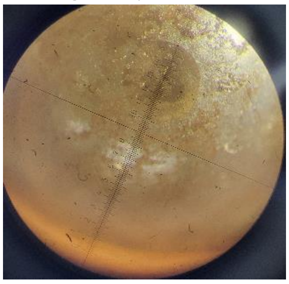
Diesel fuel + 10 % of methyl ester magnetic field 0.4Tl



Diesel fuel + magnetic field 0.4Tl



Diesel fuel + 20 % of methyl ester magnetic field 0.1Tl



Diesel fuel + 20 % of methyl ester magnetic field 0.4Tl

Fig. 5. Photomicrographs of the wear contact spot on an alloy sample SHX15 depending on % of methyl ester content in diesel fuel treated by magnetic field, sample load P = 0.5 kg, speed υ = 0.2 m/s.

Conclusions. The studies showed that the addition of methyl esters of fatty acids of rye oil led to an increase in the amount of wear (presented at Fig. 2) by 1.8 (10% esters) and 2.2 (20% esters) for the diesel samples and their mixtures with biocomponents, respectively. This can be explained by the presence of methyl alcohol in the methyl esters of fatty acids of rye oil. He leads to the dissolution of boundary films on the friction surfaces, and therefore to an increase in the amount of wear.

During the treatment of fuels with a magnetic field of 0.1 T and 0.4 T, it was established that the amount of wear (presented at Fig. 3) decrease in 1.2 and 1.5 times (10% esters, a magnetic field of 0.1 T and 0.4 T, respectively); 2.2 and 1.15 times (20% esters, magnetic field of 0.1 T and 0.4 T, respectively) times, respectively. In our opinion, treatment of lubricants with a magnetic field increases the ability to form a stronger boundary film on friction surfaces, compared to traditional diesel fuel of petroleum origin. This ability is explained by the orientation of ester molecules in interfacial space, as well as their high viscosity.

If we take the sample of diesel fuel as a control, we can conclude that the use of methyl esters of fatty acids of rye oil has a negative effect on the lubricating properties of diesel fuels. The treatment with a magnetic field of mixed fuels leads to stabilization and improvement of their antiwear properties. Based on this, the theoretical and experimental studies were considered for the electrophysical influence on the parameters of traditional hydrocarbon fuel.

The obtained results of experimental studies can be used for further scientific studies in order to obtain an evidence base for the use of the influence of a magnetic field to improve the antiwear properties of diesel and diesel fuels reformulated with biocomponents.

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