STUDY OF ANTIWEAR PROPERTIES OF TS-1 JET FUEL TREATED WITH ELECTRIC FIELD

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Abstract. A method for testing of anti-wear properties of fuels and low-viscosity fluids processed with electric field for "cylinder - the plane" tribological contact scheme has been developed. The influence of an electric field on the antiwear properties of TS-1 jet fuel has been studied.
Keywords: fuel, anti-wear properties, electric field, value of wear, wear resistance, jet fuel

1. Introduction

Wear of machine parts and mechanisms is one of the most difficult problems of modern technology. Continuous improvement of modern machines and mechanisms is directly related to improving the quality of fuel and lubricants (F&L). Improving the quality of lubricating medium (LM) in most cases can generally improve the reliability and efficiency of all mechanical equipment. Modern technology has very high reliability, but despite this, it should be taken into account that it is equipped with sophisticated hydropower units, performing important functions such as control systems in aircraft and fuel automation of aircraft engines, fuel systems in internal combustion engines and in ground equipment control systems.

Reliability of fuel and hydraulic aggregates largely depends on the uptime of friction pairs, which serve as sensory elements of automatic regulating devices, displace elements of pumps, hydraulic equipment distribution elements and other equally important components. Due to increased wear, fracture and wedge of friction pairs hydraulic failure appear, causing a need for early removal of these units out of service. The specificity of these pairs of friction requires a critical approach to these issues as for application of existing ideas concerning the impact of LM, the mechanical properties of materials; conjugate surfaces roughness, relative speed of their movement.

Today, requirements for F&L, the regime and characteristics of their operation in different conditions determine the need to improve anti-wear properties of F&L and searching for new directions and methods for achieving this.

Due to the sharp price increase of natural resources, restoring and improvement of anti-wear properties of fuels and oils is an actual scientific and technical problem of modern Tribology. Increasing anti-wear properties of fuels and lubricants and development of devices for their implementation is one of the priorities of increasing the reliability of machines and mechanisms.

Problems as for the impact of electric field on the antiwear properties of fuels and lubricants remain open. Therefore, it was decided to assess the impact of electric its drops along with the molecular forces that determine their strength.

The problem of friction and field on liquid hydrocarbons, testing antiwear properties of some F&L.

2. Problem formulation

The goal of this work was to study anti-wear properties of jet fuel TS-1 treated with electric field and to develop a test of anti-wear properties of F&L under the "cylinder – plane" tribocontact scheme.

3. Analysis of previous research and publications

Analysis of [1-3] shows that the problem of increasing anti-wear properties of fuels and oils has been examined repeatedly. In these works, the basis for recovery of waste lubricants was taken in a form of various technological operations, based on physical, physico-chemical and chemical processes to remove aging and contamination products. In [2] special attention is paid to solving such important issues as protection against corrosion and mechanical wear, protection against oxidation, resistance of lubricants to foam formation, preserving performance properties in a wide range of temperatures.

[4] shows that one way of improving performance properties of fuels and lubricants is the electrical treatment, which takes place by passing fuel through a magnetic field, while imposing high-frequency electromagnetic field with frequency equal to the frequency of precession of protons in this magnetic field. The authors of this paper found that the electrical treatment of diesel fuel reduces the time and specific fuel consumption by 2-4% at all frequencies of rotation of the crankshaft, although the greatest effect was observed at idle (fuel time consumption decreased by 8-12%). In the study of anti-wear properties of diesel fuel L-0,2-40 and L-0,5-40 it was found that electrical treatment leads to reduction of wear of SHH 15 steel friction pair in sliding friction by 40-45% and 33-38% respectively.

Number of the researchers proved that the processing of fuel with electric field, aerodynamic and electrical forces also act on These aerodynamic and electric forces are directed in the opposite direction and conditionally lower the surface tension drops, thus, resulting in a fine spray of fuel, better combustion and, consequently, lowering the toxicity of the exhaust gases [4 - 5]. It has been proved that the effect of electromagnetic fields on water, motor oils and special fluids causes the change of surface tension, viscosity and density [5]. A significant change in flow regime (increasing the number of drops and decreasing their size) happens at the expense of lowering the surface tension as a result of the application of external electric field of high tension to F&L.

The authors of this work developed, manufactured and tested a device for improving anti-wear properties of fuels and lubricants [6]. The device is characterized by compactness, ease of use, and low manufacturing costs. For the proper implementation of the specified device, the fundamentally new method for improving anti-wear properties of F&L has been developed, which allows improving antiwear properties of fuels and oils quickly at a new level [7, 8]. The experiments with thee influence of electric field on the antiwear properties of fuels and oils showed satisfactory results, which were detailed in the work [8]. In this case, the test of antiwear properties of fuels and lubricants were performed using a friction machine according to the scheme "disc - plane" linear contact; material samples included SHH15-SHH15.

Such well-known and certified methods of testing anti-wear properties of fuels and lubricants, as a method of determining anti-wear characteristics of lubricants in the four ball friction machine (GOST 9490) [9] and the method for determining anti-wear characteristics of lubricants using a friction machine SRV (ASTM D 5706-97) [10] are now widely used. There are also common methods for determining the tribological performance of lubricants with the 3 stage technique and a method of determining the tribological characteristics of F&L with a "roller-drive" scheme.

Comparative studies of F&L with different friction machines showed that in most of the cases only in machines with "linear contact" a relative compliance of test results for the same evaluation criteria of lubricating ability is observed in the form of a limit load before the appearance of a bound [2].

It is known that tests using four ball friction machine have such advantages as sufficient homogeneity of friction surfaces of working machine parts with a respect to surface quality, size and hardness, and that during testing there is almost no change in conditions of the lubricating film [9].

Research method developed and described in detail below also has all the specified advantages. However, if testing F&L with a four ball machine, not a significant amount of wear is obtained in friction of homogeneous solid spherical surfaces. When testing fuels and lubricants, which have high anti-wear properties, the magnitude of wear is very small, and in order to obtain optimal measurement spots it is needed either to extend the way of friction, or significantly increase the speed of sliding or loading. Also in this case the measurement of a medium contact spot of lower balls takes sufficient time and requires researcher’s accuracy of measurements. In general, this problem occurs in the tests of any pair of friction when a solid material rubs against a solid. Such friction pairs as "shaft - block", "cylinder - the plane," "ring - ring", "roller - drive" are not exceptions. When a solid material rubs against a soft one, especially on a "cylinder - the plane", we get a pair of friction, which is closer to the real one and models "shaft - bush" pair. The amount of wear (linear, volumetric, by weight) is greater than in the case with two identical by hardness samples. In this case, the measurement of the amount of wear becomes easier with the use of conventional profilometers and micrometers, and does not take much time.

For comparison of anti-wear properties of the two tested lubricants, it is enough to discover, in which case there is a greater or lesser amount of wear.

In our case, the main objective was to compare the anti-wear properties of fuels and low viscosity fluids in the state of supply and processed with an electric field. In this case, the lubricating medium must be submitted to a pair of friction immediately after processing by the electric field, which requires the structural improvement in friction machines and developing new methods for studying anti-wear properties of fuels and lubricants.

4. Methods and results of the experiment

In order to investigate the anti-wear properties of fuels and lubricants, processed with the electric field, a technique for examining anti-wear properties of fuels and low-viscosity fluids using a "cylinder - the plane" scheme with cylinder tribocontact and material samples of "9HS steel- LS59-1 brass" has been developed. A choise of a friction pair was determined by the fact that modern technology, particularly in hydraulic systems with plunger and plate pairs, mostly works with a pair of friction of steel and copper alloy in a tribocontact.

Testing of anti-wear properties of fuels and lubricants was carried out using the technique developed in the laboratory for tribo-technical tests and studies of the National Academy of Sciences of Ukraine and the Department of Engineering, Production and Recovery of Aircrafts of the National Aviation University. A research technique was implemented using the “PT-4TS” friction device and explained using the scheme for test of fuels and low-viscosity lubricant mediums, which is shown in Fig. 1. Technical characteristics of "PT-4TS" friction device are shown in Table 1.

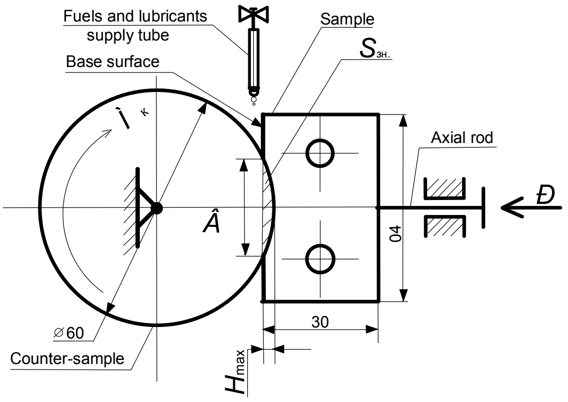


Fig. 1. A scheme of testing of anti-wear properties of fuels and lubricants, implemented on the "PT-4TS" friction device

The device is designed to determine tribotechnical properties of materials, coatings and low-viscosity fluids. A flat sample with a given normal load in a defined liquid medium is pressed to the rotational cylinder-counter sample. As a result of friction the working surface of the sample wears out and workin-off in a form of a segment hole is formed. After the test specimen measured geometric dimensions of developing and calculated parameters of linear and volumetric wear intensity.

Table 1

Technical characteristics of "PT-4TS" friction device

Basic size of cylinder-counter sample, *D*, mm	60
Basic size of a flat sample, mm	30x40x3
Relative shift velocity of a sample in contact, ϑ, m/s	0,35; 0,58; 0,85; 1,31; 2,19; 3,7
Greatest beat of sample's cylindrical surface – counter-body during counter rotation, mm	0,03
Regular load, *P*, kg	0,25 – 100
Working medium	fluid
Rotation frequency of electrical engine drive shaft, *n*, min^{1}	1400
Drive electrical engine , kW	1,5
Depending on the objectives of the experiment, it is possible to specify discrete values of friction regimes	

Working surface of a counter-sample, which performs relative rotational movement, has a diameter of 60 mm and a width of 10 mm, and is made of 9HS steel and tempered to the hardness of HRC 62. Working surface of the stationary flat sample with a length of 40 mm, a width of 30mm and thickness 3mm is made of LS59-1 brass. If necessary, samples with steel, hardened to the hardness from the minimum to the hardness of counter-sample can be used. The sample, the counter-sample, and all mounting details were washed with acetone and dried before conducting tests for cleaning surfaces from residues of products of machining and fuel.

The technique involves three steps for a test of fuels and lubricants. The first stage is artificial aging of pairs of friction with friction path being 1000 m. In order to get a constant repeatability of the process, artificial aging was conducted only in the basic fuels and lubricants. The second and the third stages are the stages of operation of friction pairs in the prescribed mode needed for studying of anti-wear properties of lubricant environments; the friction path is respectively 2000 m and 4000 m after artificial aging process. The device for processing of fuel with an electric field is placed on a friction machine with output of the original pipeline directly to the vessel with the investigated liquid. It allows not to spend time on replacement of fuels and lubricants in the friction device and to investigate anti-wear properties during their processing with electric field, which together prevents fast relaxation of charges in them. In order to have repeatability in conditions of the experiments, to prevent additional vibration and increased torque at startup of a friction device during a transition from artificial aging mode of friction pairs to the stages of their working out in the established mode, it was decided not to stop appliance friction to replace the basic fuel processed electric field. A vessel with the investigated liquid contains the valve through which a tested material merges quickly. Then fuel or lube is fed to the vessel from a device for the treatment of fuels and oils with an electric field. After testing, the liquid is drained from the vessel, the counter-sample is wiped with a dry cloth, and a test sample is removed for the subsequent measurement of the amount of wear.

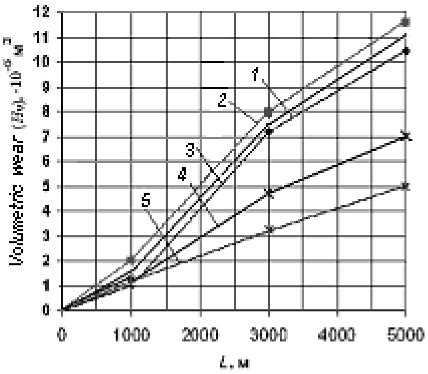
A jet fuel TS-1 was selected as a test fuel, since it has low anti-wear and low rheological properties, and certainly allows to provide a boundary lubrication. Processing the TS-1 jet fuel with an electric field was carried out for 1 hour at voltage being U = 2000 V and the field intensity $E = 1{,}1 \cdot 10^{6}$ V/m. The methods for the processing of fuels and lubricants with an electric field are described in [7].

It was found that the nature of relationships of a volumetric wear and a friction path is similar for different sliding speeds and normal loads for different samples working in the base TS-1 jet fuel and processed in an electric field. However, there are significant differences (Fig. 2 - 3):

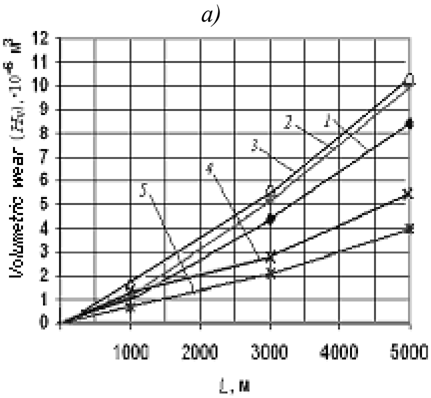
First of all, at similar values of sliding velocities, the values of volumetric wear working in an electrically treated TS-1 jet fuel are 1.2 ... 1.4 times smaller than for the samples produced in the base jet fuel. And for the same values of normal loads volumetric wear of samples working in the electrically treated TS-1 jet fuel are 1.2, 1.1, 1.3, 1.15 times smaller at P = 10, 15, 25 and 30 kg respectively and at P = 20 kg they are 1.25 times larger than for samples working in the base jet fuel;

Secondly, an increased wear for samples processed in the base TS-1 jet fuel begins at values of sliding speed at 0,55 ... 1,38 m/s at sustained normal load, and for the samples processed in electrically treated jet fuel are at 0,84 .. .1,38 m/sec speeds. There is a constant wear resistant area increase, which leads to broadening the range of normal operation of constructional parts with increasing sliding speeds.

Thirdly, with increasing of a normal load, the values of volumetric wear gradually increase and at P = 20 kg rapidly decrease. Furthermore, with increasing of a normal load up to 25 and 30 kg, the values of volumetric wear increase significantly. Thus, the optimal normal load for LS59-1 brass is 20 kg in this tribological joint.

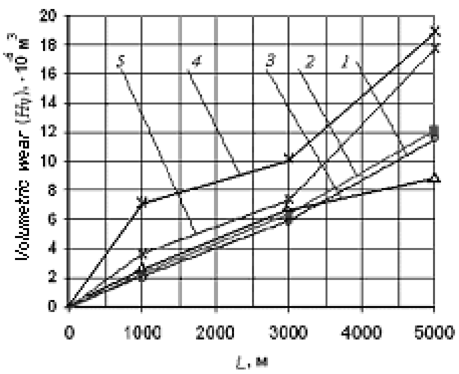


a)



b)

Fig. 2. The dependence of volumetric wear value from the friction path during the study of anti-wear properties of a basic TS-1 jet fuel (a) and TS-1 jet fuel (b) processed with electric field for one hour at voltage U = 2000 V and a field strength $E = 1,1 \cdot 10^6$ V/m at a normal load P = 10 kg: *1* - ϑ = 0.550 m/s; 2 - ϑ = 0.847 m/s; 3 - ϑ = 1.38 m/s, 4 - ϑ = 2.196 m/s, 5 - ϑ = 3.36 m/s



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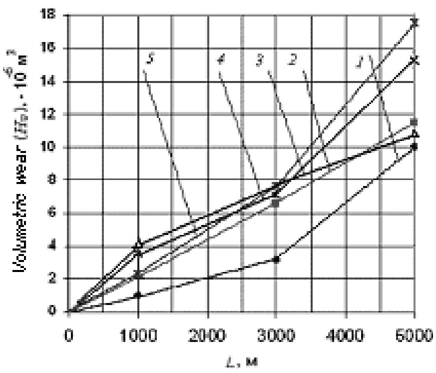

b)

Fig. 3. The dependence of volumetric wear value from the friction path during the study of anti-wear properties of a basic TS-1 jet fuel (a) and TS-1 jet fuel (b) processed with electric field for one hour at voltage U = 2000 V and a field strength $E = 1,1 \cdot 10^6$ V/m at a sliding speed ϑ = 0,847 m/s*: 1* – P = 10 kg*; 2* – P = 15 kg*; 3* – P = 20 kg*; 4* – P = 25 kg*;* *5* – P = 30 kg

5. Conclusions

A technique for examining anti-wear properties of fuels and low-viscosity fluids treated with electric field in "cylinder - plane" tribological contac scheme has been developed. The main experimental results are the following:

- For the same values of sliding velocity, the values of volumetric wear of samples processed up in the electrically treated TS-1 jet fuel are 1.2 ... 1.4 times smaller than for the samples processed in the regular jet fuel;

- For the same values of normal loads, volumetric wear of the samples processed in the electrically treated TS-1 jet fuel are 1.2, 1.1, 1.3, 1.15 times smaller at P = 10, 15, 25 and 30 kg and, at P = 20 kg, are respectively 1.25 times larger than for the samples processed in the regular jet fuel.

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11. Frequency, Linear-Oscillation (SRV) Test Machine.

Игорь Трофимов, Николай Захарчук

ИССЛЕДОВАНИЕ ПРОТИВОИЗНОСНЫХ СВОЙСТВ АВИАТОПЛИВА ТС-1 ОБРАБОТАНОГО ЭЛЕКТРИЧЕСКИМ ПОЛЕМ

Резюме. Разработано методику испытаний противоизносных свойств топлив и маловязких жидкостей обработанных электрическим полем за схемой трибоконтакта «цилиндр - плоскость». За разработанной методикой исследовано влияние электрического поля на протвоизносные свойства авиатоплива ТС-1.

Ключевые слова: топлива, противоизносные свойства, электрическое поле, величина изнашивания, повышение износостойкости.