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9. DETERMINATION OF THE MECHANISM OF FORMING THE SURFACE STRUCTURES OF ШХ-15 STEEL AT FRICTION IN THE ENVIRONMENT OF AVIATION FUELS ON THE BASIS OF ETHYL OLEIC ESTERS OF RYE OIL

TROFIMOV Igor, SVYRYD Mykhail, BOICHENKO Sergii, YAKOVLIEVA Anna, SYDORENKO Oleksandr

Presented studies are related to the spheres of aviation and machine-building. Anti-wear properties of conventional jet fuel, fatty acids ethyl esters bio-additives derived from camelina oil and their blends were investigated experimentally. It was found that lubricity of bio-additive is significantly higher comparing to conventional oil-derived jet fuel. It was found that addition of bio-additive into the composition of jet fuel leads to strengthening of boundary film, decreasing of friction coefficient and improvement of anti-wear properties of fuel blends.

INTRODUCTION

The studies described in this article relate to aviation fuel supply and aviation engineering. The world experience in the operation of aviation technology has accumulated a huge amount of statistical material on the failures of on-board systems due to the increased wear of details. A generalized study on the operational reliability of fuel systems of domestic and foreign aircraft shows that almost 30% of all accidents and disasters, up to 50% failures of aviation engines, from 20 to 40% - hydraulic and almost 10% failures of fuel systems occur due to the reduction of operational properties of fuels, and the life of pumps and other aggregates is reduced for this reason in 6-7 times.

PROBLEM ANALYSIS

Improving the reliability, durability and cost of aviation engines is a complex problem and its solution is achieved at all stages of the design, manufacture and operation of products. An important condition for the implementation of reliability and durability, laid in the design of the engine, is to increase the operational properties of fuel and lubricants. Continuous improvement of aviation and ground technology, providing reliable, economic and durable work of its put forward high requirements for the quality of the properties of lubricants. The resource and reliability of aviation engines are determined by a combination of physical and chemical, operational and environmental properties of fuels and lubricants.

As is known, the most common cause of deterioration in the quality of lubricants is oxidation with the formation of resins, varnishes, carbon deposits, carbons, carbonates and other sediments, as well as corrosion of insoluble products.

Modern requirements to aviation fuels, the regime and the stable properties of their work in different conditions determine the need to increase the tribochemical properties of existing petroleum aviation fuels and new mixtures based on biocomponents.

That is why the issue of studying and improving the antiwear properties of modern fuels for automotive and jet engines is one of the components when considering the priority directions of ensuring the reliability of motor vehicles and friction units. Improvement of operational properties of fuel and lubricants is a topical scientific and technical problem.

PROBLEM RESOLUTION

Reliability of fuel and hydraulic units of aviation equipment depends to a great extent on the performance of precision friction pairs. Increased wear, fracture and jamming of friction pairs cause hydraulic failure, and the need for a planned replacement of worn parts appears. The most common defects are: jamming of plunger, plate and spool pairs, the destruction of roller bearings, the wear of plunger bearers and so on. The specificity of these friction pairs requires a critical approach to the use of existing representations of the relative influence of lubricating media, mechanical properties of materials, roughness of the conjugate surfaces, and the speed of their relative displacement.

Today, in the world, great attention is paid to alternative sources of energy, in particular, alternative fuels. But in most cases, this is fuel for cars. Given the rapid growth of the aviation park and the large volumes of refueling of one aircraft, compared with the car, the issue of alternative fuels for aviation engines remains relevant. Particular attention is required to study the operational properties of such fuels, since they directly affect the safety of flights. In the works [1] it has been established that alternative fuels for air-jet engines (AJE) derived from the plant basis are characterized by low lubricating properties, taken from aviation fuels of petroleum origin. At the same time, there are reports of quite good lubricating properties of vegetable oil esters [2]. Taking into account the known data on the lubricating properties of vegetable oil esters, it is interesting to study their effect on the anti-wear properties of fuels for gas turbine engines.

PURPOSE AND TASKS OF THE STUDY

The purpose of this work was to study the anti-wear properties of blended vegetable and mineral fuels for air-jet engines containing ethyl esters of ridge oil. Accordingly, one of the tasks of the study was to compare the antiwear properties of these mixed fuels with anti-wear properties of mineral fuels for gas turbine engines. The work was carried out within the framework of the scientific theme 182ДБ18 "Improvement of operational characteristics of fuels for gas turbine engines, safety of aviation transport and its environment".

The object of the study was to increase the antiwear properties of blended aviation fuels containing ethyl esters of rye oil.

The subject of the study was the aviation fuel modified by the plant basis and the influence of ethyl esters of fatty acids of rijive oil on the patterns of formation of the tribotechnical characteristics of the mixture of aviation fuels.

RESULTS OF THEORETICAL AND EXPERIMENTAL RESEARCHES

As is known, the anti-wear properties of fuels for PWD determine the reliability and life of aircraft fuel assemblies, in particular their friction pairs [3]. These vapors operate in rolling, friction and combined friction modes at different loads, temperatures, pressures, relative speeds under liquid and lubrication conditions.

The lubricating properties of fuels depend on their chemical composition, viscosity, thermal oxidation stability, the content of mechanical impurities, the presence of surfactants [4]. At high specific loads, there is usually a semi-rigid friction when the friction surfaces are not completely separated by fuel. In the case of semi-friction, the anti-wear properties of fuels for AJE are determined by the viscosity of the fuel, which provides the hydrodynamic effect of the separation of the friction surfaces with the liquid layer, as well as the presence in the fuel of surface-active substances that form on the friction surface an absorption layer of high strength, which separates the surface of friction and thereby reducing the coefficient of friction and wear components [5].

Analysis of literary sources [1–6] shows the interest of the authors in experimental and theoretical developments in increasing the antiwear properties of precision friction pairs and studies of the effect on the anti-wear properties of various components of fuels and oils. One of the directions for extending the term of operation and restoration of tribological joints is the tribodomodification of friction surfaces due to the formation of stable oxide films, through the use of modified or energy-modified lubricants.

During the experiment, the anti-wear properties of aviation fuel were investigated JET A-1, ethyl ester of fatty acid rigia oil and mixtures JET A-1 with plant biocomponents. Brand JET A-1 meets the requirements ASTM D1655. Biocomponents were represented by a mixture of ethyl esters of fatty acids rigia oil that meets the requirements EN 14214, specially modified for use as a fuel component for AJE. The modification was carried out by vacuum fractionation in accordance with the developed technology [6]. Samples of fuel mixtures contained the specified biocomponents in the amount 10, 20, 30, 40 and 50 %.

Typically, the anti-wear properties of fuels for RHD are estimated by the size of the wear of a characteristic friction pair. Wear in a medium of a certain kind of fuels of an arbitrary friction pair can not characterize the lubricating properties of this fuel unambiguously. Changing material parts, test modes and other factors can significantly affect the wear of the friction surfaces. In this regard, the evaluation of anti-wear properties is carried out under strictly regulated conditions [7].

To study the state of friction surfaces and the coefficient of friction, a complex developed by the authors was used to study the tribological characteristics of fuel and lubricants. To investigate friction and wear materials, a reversible displacement installation, developed by the authors, was used [8].

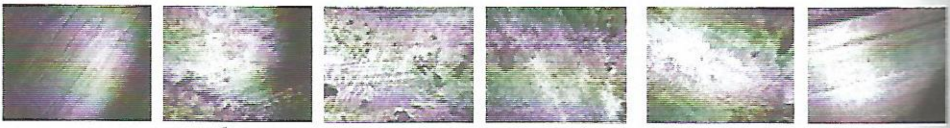
The research was conducted in two stages: on the 1st - the way passed by the sample was 3 km; 2nd - the path reached 6 and 17 km, according to the scheme of friction "finger-plane", material samples ШХ15 - steel 45 (tempered to the value HRC 52), $\vartheta = 0{,}20$; P = 5 H, frequency = 1 Hz. Dimensions of the sample finger: diameter - 4 mm, length - 33.4 mm. Assessment of the demolition of samples was performed by profiling the wearing spots and obtaining the amount of volumetric wear according to the method and is reduced to 1 km.

1st stage. Working on a friction machine was carried out in lubricating media of such samples: No. 1 - JET A-1; № 2 - ethyl ester of fatty acid (EEFA) of rigia oil; No. 3 - JET A-1 + EEFA 20% of rigia oil; № 4 - JET A-1 + EEFA 30% of rigia oil; № 5 - JET A-1 + EEFA 40% of rigia oil; № 6 - JET A-1 + EEFA 50% of rigia oil. Experimental studies were carried out at the complex to determine the anti-wear properties of fuel and lubricants by the method described in the paper [13]. The results are presented in Table 1.

Tab. 1. Tribotechnical characteristics of friction pair ШХ15 - steel 45 in different lubricating (samples No. № 1-6) at T = 353 K, along the path of 3 km

Sample	μ (coefficient of friction)	I_v, mm^3	I_v,mm^3/km	EEFA %
№ 1	0,4	0,078	0,00975	0
№ 2	0,35	0,0034	0,000425	100
№ 3	0,3	0,0045	0,00056	20
№ 4	0,3	0,0025	0,00031	30
№ 5	0,35	0,0012	0,00015	40
№ 6	0,35	0,0016	0,0002	50

According to tribological research, it is clear that mixtures № 5,6 have roughly identical wear parameters, almost 50 times smaller than in JET (Table 1). The formed surface films in JET (Fig. 1a) have an unstable unformed appearance, and in the EEFA impurities the surface is covered by 60-70 %% of the area created by the protective layer during friction (Fig. 1, d,f). Use of the additive № 3 with 30% EEFA reduces wear by 30 times with a coefficient of friction 0,3. The increased friction coefficient in samples № 5,6 is due to an increase in the density of the mixture due to the EEFA, which emits a clearly expressed direction of the surface protective films (Fig. 1 d, f). By comparing the friction surfaces, it can be argued that the surface that worked worked out a 100% EEFA (sample number 2) of raspberry oil (Fig. 2b), which received a thick layer of oil in the contact area and a more uniform relief than the friction surfaces developed in the basic JET A-1 (Fig. 2a), and the oxide films are more subtle and elastic.



a b c d e f

Fig. 1. Microphotographs of friction surfaces (increased by 100 times): a - working in the environment of JET A-1; b - working in an environment of 100% EEFA of rigia oil; c - working in a medium of JET A-1 + EEFA 20% of rigia oil; d - working in a medium of JET A-1 + EEFA 30% of rigia oil; e - working in a medium JET A-1 + EEFA 40% of rigia oil; f - working in a medium of JET A-1 + EEFA 50% of rigia oil

This entirely explains the lower value of the coefficient of friction and the amount of wear for the same traversed friction path. Moreover, in Fig. 2 b lines of oxide films are clearly visible. As the blends of different proportions work out, the film samples become considerably larger in length and width than those of the sample of raspberry oil produced in EEFA, and their more contrasting coloring makes it possible to assert that the films of the friction surface of the sample in Fig. 2 b have a smaller thickness and are more elastic. In fig. 2 d, e clearly shows that the friction surfaces become uniform throughout the wearing spot, the oxide films are smaller in size, but focusing tightly throughout the surface. This entirely explains the reduction of wear for samples of 30% and 40% of JET A-1 + EEFA. In fig. 2 f, it is seen that the friction surface becomes smoother as compared with the surfaces of friction in Fig. 2 d and Fig. 2 e, but the oxide films are displaced, and the microniveness is increased. This explains the slight increase in the size of the wear and the coefficient of friction.

Explain the effect of reducing the amount of wear when the aeration fuel of the fatty acid esters of rijive oil is added to the aviation fuel can be explained by the fact that the esters increase the polarity, and hence the adsorption capacity of the ether molecules and the displacement of the electron density to the oxygen atoms of the carbonyl group. It is also worth noting the well-known fact that the strength of oil films on an ester base is up to 22000 kg/sm2, while for mineral oils, about 4500 kg/sm2 and synthetic oils of about 9000 - 12000 kg/sm2. In this part of the work it was found that adding esters to the base aviation fuel JET A-1, we received: strengthening the oil film on the surface of the friction; increasing the grafting of metal surfaces; an additive in the form of fatty acids, which is included in the esters.

The second stage of the research is devoted to the determination of the tribological parameters of the strength of the oil films on an ester base. For this purpose, in the same tribological conditions, long-term research was carried out on the path of 5.76 km and 17.28 km with loadings of 5N and 22N (Fig. 2).

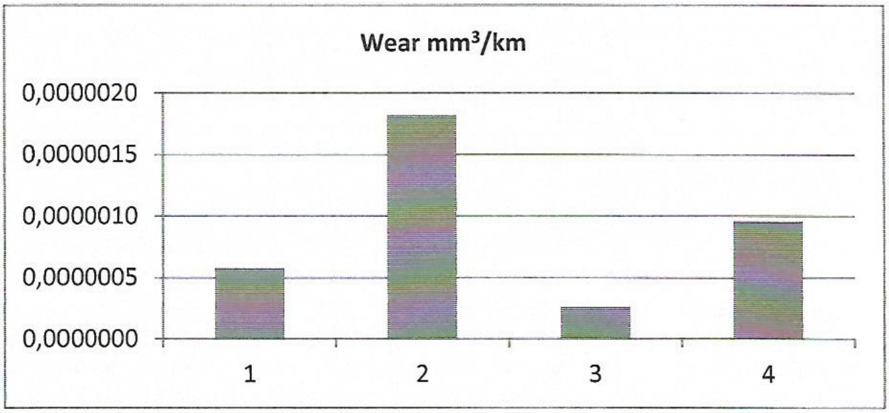


Fig. 2. Wear of steel ШХ15 in mm^3 in 1 km way (ШХ-15 on Ст45 (3) in ASTER + JET) 1- load normal 5H; way 5.76 km) 2 - load 22H, way 5.76 km; 3 - load normal 5H; the way 17.28 km; 4 - load normal 22N; way 17.28 km

From the obtained results it is evident that surface smoothing occurs with the formation of a small number of thin films (Fig. 3), which correlate with the size of wear (Fig. 1,2). Where it is obvious that with an increase in loading of almost 4,4 times, the wear and tear also has to increase, but in this case the wear has increased in 3,1 times. On the topography of the surface it can be seen that with increasing loading the surface is smoothed, on the way 5,76 km.

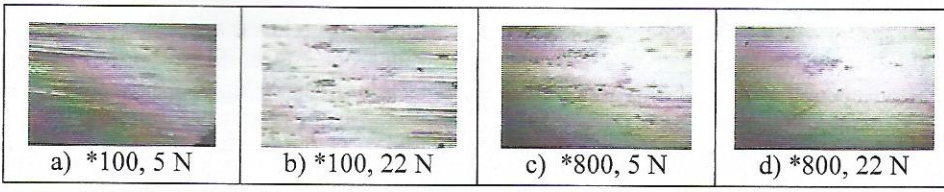


Fig. 3. Topographic survey of the surface on the way 6 km

On the surface of the samples, which passed almost 17 km there is a smoothing, already, at a load of 5N with the formation of protective films around the center of the sample, which are depicted in Fig.4b

Significant formation of surface films were tested at a load of 22 N on the way 17 km, but the wear is much smaller (Figure 2-4) compared with the path at 5.76 km (Fig. 2-2). This indicates that the formation of protective films greatly protects the surface from wear (Fig. 4-b, d).

From tribological researches testifies that with increasing of loading demolition increases. From the load, formed surface films begin to collapse but remain in the contact area.

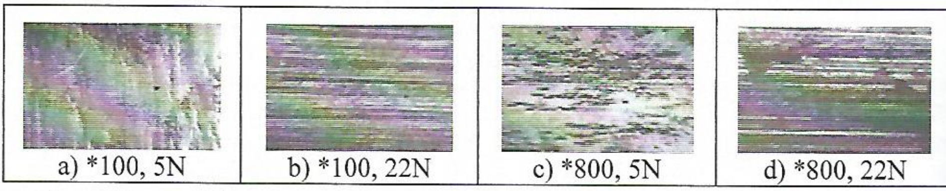


Fig. 4. Topographic survey of the surface on the way 17 km

The amount of wear, depending on the path (Fig. 2-1 and 2-4), differs by 50%, indicating a lower dependence of the tribological characteristics of the friction pair ШХ-15 on St45 (hardened) in a 50% solution of ESTER + 50% JET.

CONCLUSIONS

The study of samples of mixed fuels showed that fatty acid esters of flaxseed oil exhibit the ability to form a stronger boundary film on friction surfaces compared to fuel for air jet engines of petroleum origin. This ability is due to the surface activity of the molecules of esters and their high viscosity. Taking a sample of JET A-1 fuel for control, we can conclude that the use of esters of ridge oils positively affects the lubricating properties of fuel for air jet engines. The influence of changes in tribological parameters on the changes in the surface topography mechanism when working in a solution of 50% ESTER + 50% JET is considered. It has been established that during the considerable load the process of formation of protective tribological plates is activated and affects the wear and tear much more active than the time of work. With the condition of increasing the path by 3 times the wear decreases by 7 times.

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OKREŚLENIE MECHANIZMU KSZTAŁTOWANIA STRUKTUR POWIERZCHNIOWYCH STALI ШХ-15 PRZY TARCIU W ŚRODOWISKU PALIW LOTNICZYCH NA PODSTAWIE ESTRÓW ETYLOWO-OLEINOWYCH OLEJU ŻYTNIEGO

Streszczenie

Prezentowane badania dotyczą sfer lotnictwa i budowy maszyn. Badano eksperymentalnie właściwości przeciwzużyciowe konwencjonalnych paliw do silników odrzutowych, bio-dodatków estrów etylowych kwasów tłuszczowych pochodzących z oleju lniankowego i ich mieszanek. Stwierdzono, że smarność bio-dodatku jest znacznie wyższa w porównaniu z konwencjonalnym paliwem lotniczym pochodzącym z ropy naftowej. Stwierdzono, że dodanie bio-dodatku do składu paliwa do silników odrzutowych prowadzi do wzmocnienia filmu granicznego, zmniejszenia współczynnika tarcia i poprawy właściwości przeciwzużyciowych mieszanek paliwowych.