The relevance of lubricating properties indicator into the Russian standard for civil aviation jet fuels introduction

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Abstract. The fuel for civil aviation jet engines is aviation kerosene. In the fuel systems of aircraft and aircraft engines, they perform a number of functions, one of the main ones being the lubricating function. The lubricity of fuels depends on many factors, including the technologies for their production, which are constantly changing. The lubricity of Russian fuels for civil aviation is not standardized and not controlled. A comparative assessment of the lubricity of fuel brands used in civil aviation on a four-ball friction machine is shown in the article. The introducing an indicator characterizing the lubricity of fuels into the Russian standard for jet fuels relevance is justified.

1. Introduction
Aviation jet fuels are used in all jet engines and performs a number of important functions, one of which is lubricity [1]. The reliability of the aircraft engines fuel system friction pairs depends on the fuel lubricity. The most susceptible to wear are friction pairs of expensive plunger pumps. There are: plunger – wobble plate; plunger – clip [1, 2].

At the moment, Russian refineries produce for civil aviation the following jet fuels brands: TS-1, RT in accordance with GOST 10227–86 [3] and Jet A-1 in accordance with GOST 32595–2013 [4]. In these standards, 26 quality indicators are standardized for the TS-1 and RT brands, and 18 for Jet A-1. At the same time, the standard for Jet A-1 fuel contains an indicator characterizing the lubricity, while the standard for TS-1 and RT fuels does not have such an indicator. It is also worth noting that the standard for Russian fuels for supersonic aviation GOST 12308–2013 [5] also specifies the lubricity. That is, the lubricity of the TS-1 and RT fuels was once assessed only by qualification test methods when they were put into operation. The raw materials and technologies for obtaining these fuels at that time were different from the existing ones.

To date, the airworthiness directives of the European Aviation Safety Agency (EASA) contain claims to the quality of the TS-1 fuel, and, first of all, to its antiwear properties (lubricity): EASA AD No.: 2017–0065 [6], EASA PAD No.: 17–023 [7], EASA CRD of PAD No. 17–023 [8]. For example, the resource of a number of foreign engines operating on TS-1 fuel was reduced by 50 % [9, 10]. This circumstance can be caused by both subjective and objective reasons.

The fuels antiwear properties depend on many factors: hydrocarbon composition, presence of
heteroatomic compounds, purity, presence of surfactants, etc. At the time of the lubricating properties assessment by the qualification test methods the processes of obtaining jet fuels TS-1 and RT were direct distillation and hydrogenation processes, respectively. A number of additives must be introduced into hydrotreated fuels, including antiwear additives, which have also changed today [11, 12]. Also, a number of Russian oil refineries produce the so-called mixed fuel TS-1, which includes both direct distillation products and products obtained through secondary oil refining processes [13]. Obviously, these factors affect the lubricity of aviation fuels, which is not controlled.

2. Method

There is a wide variety of methods for assessing the lubricating properties of fuels and lubricants, many of which can be applied to assess the lubricating properties of aviation fuels. To assess the lubricating properties of domestic fuels for supersonic aviation and fuel Jet A-1, the standards provide for the foreign method BOCLE GOST 33906-2016 [14] and ASTM D 5001-10 [15]. The corresponding device is manufactured by the only global manufacturer.

At the same time, it does not have any advantages over many other methods. It does not simulate the operation of aviation gas turbine engines friction pairs, as evidenced by the phrase in the specified standard: the BOCLE test method is not a direct reflection of the operating conditions of engine parts. It is also noted there: a number of fuels with a high content of certain sulfur-containing compounds may show abnormal test results. Thus, this method is not preferable for TS-1 sulphide fuel.

A simple and reliable four-ball friction machine can be used to carry out a comparative assessment of the lubricating properties of aviation fuels (Figure 1, 2). The essence of the method is to determine the critical load – load at which there is a loss of fuel lubricity, – based on the results of successive loads on a sharp increase in the wear spot diameter.

**Figure 1.** Block diagram of a four-ball friction machine: 1-electric motor with brake, 2-friction unit, 3-loading device, 4-control panel, 5-stand, 6-speed control unit [16].

**Figure 2.** The principle of operation of a four-ball friction machine: a) - loading diagram of a ball pyramid; b) - diagram of a four-ball cage; 1 - stationary balls; 2 - a rotating ball; 3 - investigated oil [17].

Comparative evaluation was carried out for three samples of various grades aviation fuels and a sample of composite fuel (TS-1 + RT), taken from the aircraft tank, according to the standard method GOST 9490-75[18].
3. Results and discussion
The experimental results are shown in Figure 3. The figure shows that these fuel samples have close critical loads. At the same time, the RT fuel sample showed the best antiwear properties under these test conditions, the worst – Jet A-1.

Various indicators can be used as an indicator of the aviation fuels lubricating properties, there are critical load, wear spot diameter, etc. One of the indicators can be the calculated indicator of antiwear properties, expressed as a percentage, proposed by well-known chemotologist A. Aksenov [19]:

$$K = \frac{P^t_{c}}{P^r_{c}} \cdot \frac{I_r}{I_t} \cdot 100,$$

(1)

where $K$ - antiwear properties indicator, %;
$P^t_{c}$ - critical load received on the test fuel, kgf;
$P^r_{c}$ - critical load received on the reference fuel, kgf;
$I_r$ - wear of metals in the reference fuel, mm;
$I_t$ - wear of metals in the test fuel, mm.

Based on the experimental data, the antiwear properties of the aviation fuels investigated samples are shown in table 1. RT fuel, which showed the best antiwear properties, was taken as the reference fuel.

| Fuel   | Antiwear properties indicator, % |
|--------|-----------------------------------|
| RT     | 100                               |
| TS-1   | 98                                |
| Jet A-1| 96                                |

Thus, the indicator characterizing lubricating properties into the Russian standard for aviation fuels for civil aviation introduction is relevant. Various indicators can be used as such an indicator, including
the calculated indicator of antiwear properties obtained from the tests results on the four-ball friction machine. It is important to carry out comparative tests to assess the lubricating properties of aviation fuels samples obtained at various Russian refineries for an objective conclusion on the current state of affairs in this issue.

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