

# *Trends of Development in the Use of Modified Oil Fractions in Aviation*

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**Abstract** — The paper is devoted to review of existing aviation fluids, analysing their weaknesses and technology trends create aviation fluids, kerosene, lighter-oiling materials on the basis of modification of petroleum products.

**Keywords** — *hydraulic fluid; petroleum; composite; lighter-oiling material.*

## I. INTRODUCTION

Research and development of compositions based on chemically pure hydrocarbons and prepared hydrocarbon fractions occupy an important place in the creation of new lighter-oiling material for modern aviation.

Trends in the development of modern technology are characterized by the intensification of the use of petroleum products: an increase in operating temperatures, qualitative and quantitative growth of specific mechanical, electrical, energy, temperature, corrosion, thermal and other loads.

In-depth primary petroleum refining requires careful selection of source oils with a certain group balanced with chemical, elemental and fractional compositions. At the same time, it is highly desirable that the content of heterocyclic compounds is minimal. It is necessary that the content of elemental and mercaptan sulfur was also minimal [2].

A set of technological installations for the secondary processing of raw materials included a mandatory process of catalytic cracking of various schemes of catalytic reforming, alkylation and a mandatory set of hydrogenation processes (advanced hydrocracking, hydrotreating, etc.). The total set of these processes should correspond to the modern Nelson's criterion, about 8-10 units.

All processes must necessarily be provided with modern methods of quality control and quantity of developed lighter-oiling material: chromatography-mass spectrometers, chromatographs of various modifications, EPR and NMR

spectrometers, x-ray instruments, a large number of sets of samples of petroleum products, service personnel must be of the highest qualification [3].

## II. JET FUEL FOR SUPERSONIC AVIATION

In air-jet engines, three types of fuels differing in fractional composition are used. The first type of jet fuel, which is most common, is kerosene with boiling limits 135/150-250/280 °C, these include T-1, TS-1 and RT. The second type is a fuel of a wide fractional composition of 60-280 °C, which is a mixture of gasoline and kerosene fractions, this type includes fuel T-2. The third type - jet fuel for supersonic aircraft - weighted kerosene-gas oil fraction with boiling limits 195-315 °C, this type includes fuel T-6, T-8V.

These fuels can be divided into fuel for the engines of subsonic aircraft and fuel for the engines of supersonic aircraft. This division is due to the fact that the temperature conditions of fuel use in these engines differ significantly. In supersonic aircraft fuel is heated by aerodynamic heating of the entire structure of the aircraft. When the flight speed is more than twice the speed of sound (2M), the fuel can be heated to 150-180 °C (table. 1).

Very stringent quality requirements are for jet fuels for supersonic aircraft.

In particular, they should burn steadily without carbon deposits in a fast moving air flow with large surpluses of the latter, ensure reliable engine start in any conditions, have the maximum possible combustion heat [4].

With the development of aviation technology requirements to the fuels became more rigid. With the advent of supersonic aviation sharply tightened requirements for the thermo-oxidative stability of fuels. With the increase in the capacity of the fuel tanks of transport aircraft and bombers, it was necessary to increase the speed of refueling, which increased the risk of

accumulation of static electricity in the fuel and required the use of means of combating this phenomenon by introducing antistatic additives. The requirements for high-density fuel for high-speed aircraft with long duration supersonic flight associated with its high consumption are especially important for aircraft with limited capacity fuel tanks, such as fighters. In supersonic aircraft, the space for fuel placement is limited. Therefore, they should use high-density fuel and high enough heat of combustion to provide greater power and range [5-7].

TABLE I. CHARACTERISTICS OF SUBSONIC AND SUPERSONIC EUROPEAN TRANSPORT AIRCRAFT

Characteristics		
Characteristic	Subsonic airplane SuperVC-10 with engine Conway RCO 43D	Supersonic airplane Concorde with Olimpus 593
Maximum total useful weight, kg	150 700	167 500
Maximum fuel consumption rate, kg	69 300	83 200
The ratio of the mass of fuel to the mass of the aircraft	0,46	0,54
Cruising airspeed	880	2320
Cruise fuel consumption rate, l/passage.-km	0,036	0,058

These requirements are most fully ensured by a certain chemical composition of fuels, in particular, by the maximum content of naphthenic and isoparaffinic hydrocarbons in them. Fuels are obtained by isolating the appropriate fractions during the primary distillation of oil. Separate brands of fuels undergo hydrofining for purification from sulfur, acids and some parts of aromatic hydrocarbons. Given there are these severe restrictions, the required chemical composition and technology for producing without the use of deep chemical conversion processes, jet fuels can be obtained only from certain oils, whose resources are limited, and nowadays they are practically exhausted.

Nowadays, Russian regulatory standards provide for the production of jet fuels of the following grades:

- subsonic TS-1, T-1 (analogue - USA YR-4);
- transitional rocket fuel, which can be used for both subsonic and supersonic aircrafts (analogue - USA YR-5);
- supersonic T-6 T-8V (analogue - USA 1R-6).

T-2 fuel nowadays is not available and is considered a backup. T-8V fuel was first introduced in 1968 specifically for the first supersonic civil aircraft of the USSR - Tu-144, it can be used for military supersonic aircraft and other techniques [8-10]. In addition to aircraft, T-6 fuel is used in the following rocket weapons as the main (duplicate) brand:

- 3M80, 3M82 – antiship missile;
- X-55 – strategical cruiser missile;
- ZM14, ZM45 - highly-accuracy cruiser missile as part of the missile system «Kalibr»;

- R-500 - cruiser missile as part of the missile system «Iskander M».

T-6 jet fuel refers to thermostable jet fuel and is a gas oil fraction (195-315 ° C) of direct distillation of oil (or products of secondary processing), subjected to deep hydrogenation, as a result of which sulfur compounds, resins and unstable hydrocarbons are removed from the fuel and most aromatic hydrocarbons are converted to cyclanes. An antioxidant and, if necessary, antiwear additive is added to the fuel. Fuel has a high density and flash temperature, high heat of combustion, low sulfur and aromatic hydrocarbons and has high thermal stability.

The unique equipment of vapor-phase hydrogenation units made it possible in one step at high pressures (25-30 MPa), temperatures (380-400 ° C) and low space velocities (1-2 h<sup>-1</sup>) to obtain only a special catalyst loaded into the reaction columns with a special catalyst from one straight-run kerosene-gas oil fraction (fraction 190-320 ° C) of the Trinity-Anastasia oil of the fourth horizon, deep-hydrogenated high-quality jet fuel [11-12].

The multi-stage technology for the production and shipment of T-6 fuel includes the following stages at the facilities of an oil refinery (refinery), chemical plant (RP), and commodity production:

- hydrogenation of raw materials under pressure on a special catalyst on high pressure blocks (blocks 130,131,136);
- stripping and alkalizing of the hydrogenate from hydrogen sulfide followed by washing from traces of alkali with water (objects 149 / 172,1669);
- atmospheric vacuum distillation with the allocation of fuel distillate T-6 at the installation of 209 refineries RP;
- introducing an additive composition into a distillate of a refinery fuel RP;
- certification and shipment of fuel RP (4).

### III. NEW RUSSIAN SYNTHETIC AVIATION WORKING FLUIDS

Currently, most aviation working hydraulic fluid (HF) is produced on the basis of petroleum oils obtained using extraction and hydrocatalytic processes.

The main disadvantage of oil HF is a high fire and explosion hazard and a tendency to mechanical destruction.

Because of this, during operation of the aircraft, the viscous and temperature properties deteriorate; the foam and sludge formation of the HF increases, and the life of hydraulic devices and hydraulic systems decreases.

To ensure modern aircraft competitive domestic HF, a new domestic ASHIO hydraulic fluid was developed and manufactured.

ASHIO (aviation synthetic hydraulic oil) is the first fully synthetic domestic HF, its viscosity is 9 mm<sup>2</sup> / s at 50 ° C.

The fluid contains an improved package of functional additives (thickening, antioxidant, anti-aging and anti-foam additives, etc.).

The created HF ASHIO has operational properties significantly higher than those of traditionally used fluids.

It is impossible to create a completely non-combustible fluid; therefore, the requirements for non-combustibility have been replaced by the requirements for fire and explosion safety.

Phosphoric acid esters are prospect basic components of fire and explosion-proof HF, since they are fire resistant, satisfactorily combine thermal stability, viscosity-temperature and lubricating properties

The disadvantages of such fluids include high toxicity, chemical aggressiveness and poor compatibility with hydrocarbon oils [6].

Currently, these fluids are used in most hydraulic systems of the civil aviation aircraft (Tu-214, Il-114, Be-200).

The main directions of research work to improve phosphate HF are to increase thermal oxidative and thermal stability; improved hydrolytic stability; range extension of operating temperatures.

To increase the competitiveness of domestic phosphate liquids, SRISU together with CIAM, 25 State Research Institutes of the Ministry of Defense, ARRIOR and others developed a new domestic working fluid EPHF.

Experimental-industrial batch of EPHF is made in JSC "NC "Rosneft" [16-17].

EPHF (explosion-proof hydraulic fluid) is the latest domestic HF 9 mm<sup>2</sup>/s at 50°C based on a mixture of esters of phosphoric acid.

This fluid retains thermo-oxidative and hydrolytic stability.

As a result of the research conducted in CIAM, it was found that in these indicators EPHG exceeds NFF-5u.

Thus, the EPHG has a lower viscosity at -60 °C after oxidation, the acid number of oxidized oils is within the limits of convergence.

In terms of hydrolytic stability, EPHG has the best indicators of changes in the acid number, pH and corrosion of copper

The achieved improvements are obtained by changing the composition of the base mixture of esters and using an imported additive that counteracts their destruction.

But EPHG, in comparison with NFF-5u, has a lower flash point, increased foaming, reduced anti-wear ability and less stability after voicing.

#### IV. STATUS AND PROSPECTS OF IMPROVEMENT OF OILS FOR AVIATION

The main function of oils intended for operation in gas turbine engines of aircraft and other aircraft is to ensure

minimum wear of parts and friction units of the engine over a life of thousands of hours and to remove heat from the bearings.

Thermo-oxidative stability (TOS) of the oil should guarantee the preservation of its functional properties and the absence of deposits of oil oxidation products in the oil pipelines and other elements of the engine oil system that impede the normal operation of the gas turbine engine.

A feature of jet aircraft created in our country has been and still remains wide, in comparison with the technology of foreign countries with their own engine manufacturing, the use of mineral oil based on high quality and relatively low cost of aviation oils.

Oils such as MS-8p (OST 38101163-78) and MS-8rk (TU 38.1011181-88) are successfully used in gas turbine engines of aircraft, helicopters, and also gas turbine engines used in gas pumping units for gas transportation.

Mineral oil MS-8p is produced by Novoil OJSC (Novo-Ufimsky Oil Refinery OJSC), AviaTechMas CJSC, and Kvalitet-Avia LLC and is used to lubricate gas turbine engines (up to 150 °C) and to prepare oil mixtures for turboprop engines (TPE).

Along with it, MS-8rk mineral working and conservation oil is produced for lubricating and preserving aircraft engines, equivalent in lubricating properties to MS-8p.

Mineral oils are used to lubricate the engines of Il-62, Il-76, Il-86, Tu-134, Tu-154 and Yak-40 aircraft (including their various modifications).

AI-20, AI-24 type turboprop engines use SM-4.5 aviation oil mixture (OST 54-3-1U5-72-99), produced on the basis of MS-8p and MS-20 mineral oils.

For a long time, aviation oil mixtures were prepared directly at the place of operation of the aircraft.

However, in recent years, the SM-4.5 oil mixture has been produced at the enterprises of Qualitet-Avia LLC and AviaTechMas CJSC under factory conditions, which, undoubtedly, contributes to increasing the operational safety of the aircraft.

Back in the 1970s, mineral oil MN-7.5 u was developed to replace oil mixtures in turboprop and turbofan engines of aircraft, which by the beginning of the XXI century was outdated and is not available.

#### V. CARBON FIBERS AND COMPOSITES

The introduction of carbon fibers into polymeric materials made it possible to create a fundamentally new class of structural materials - carbon plastics. They are Structural Materials based on a polymer matrix reinforced with continuous or discrete carbon fibers.

MC-21 was conceived as an innovative aircraft. The innovations are for the first time in Russia and earlier than many leading aviation manufacturers, the aircraft will have a composite wing. It is fundamentally important that this is not just about the widespread use of composites, but about their use in highly loaded structures (see Figure 1). This in turn has a

significant impact on the aerodynamic layout and aerodynamics of the aircraft. Traditionally, aerodynamics try to increase the lengthening of the wing (the ratio of the wingspan to the middle chord of the wing), since this helps to reduce drag. However, this desire rests on an increase in the mass of the structure, which makes us look for an optimum, a compromise.

Depending on the type of reinforcing carbon material, carbon fiber reinforced plastics are divided into carbon fiber.

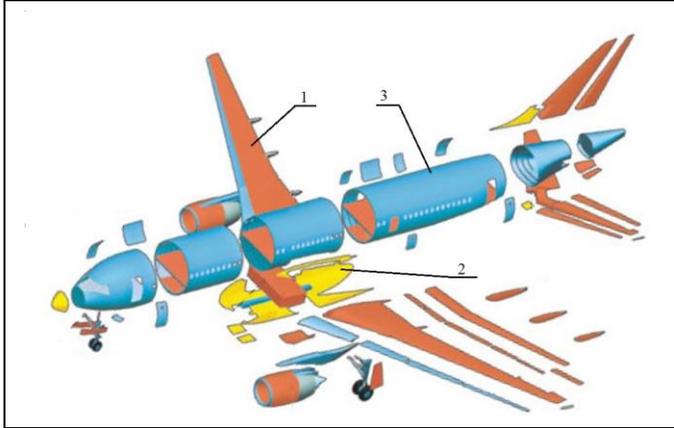


Fig. 1. Distribution of carbon materials in MC-21 (1 – Metal; 2 – Carbon Fiber Composite materials of new generation; 3 – Fiber glass composite materials))

## VI. CARBON FIBERS AND PRETEXTANTS

Carbon fibers are made using continuous carbon filaments and tows. They have low thermal conductivity and electrical conductivity, but still their thermal conductivity is 1.5-2 times higher than that of fiberglass. They have a small and stable coefficient of friction and have good wear resistance. The temperature coefficient of linear expansion of carbon fiber in the range of 20-120 °C is close to zero

Despite the objective difficulties that exist in the development and application of composite materials in aircraft and helicopter engineering, modern science is looking to the future with confidence. Every effort is made to ensure that the application and production of composite materials are qualitatively expanded and improved. In Russia, much is being done at the state level to implement the results of scientific activities [20].

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