PHYSICAL AND CHEMICAL FEATURES OF FUEL A-1 AND LUBRICANTS FOR MLAS MOTORS AND THEIR EFFECT ON ENVIRONMENT

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Abstract: *Jet fuels are liquids of liquid hydrocarbons and are designed for jet propulsion. In principle, these are kerosene fractions or mixtures of kerosene and benzene fractions with different additives. The first jet fuel used for the propulsion of airborne gas turbine engines was light petroleum, in the United Kingdom called kerosene. Today, JET A-1 is in use in our area, which is a kerosene fraction of oil with a boiling temperature in the temperature range of 170 ° C to 300 ° C (in its quality meets the requirements of military and civil aviation). In ensuring safe operation of jet engines in all regimes and in all fuel conditions, they must have a secure quality. By chemical composition jet fuel are complex compounds and consist of the basic four groups of hydrocarbons: paraffin, naphthene, aromatic and olefin. Gases and particles which result from combustion of aircraft fuel are: water vapour (H2O), carbon dioxide, CO2, nitrogen monoxide, NO, nitrogen monoxide, NO2, sulfuric oxides, SOx and soot.*

Key words: *Jet fuels JET A-1, lubricant, turbojet engine, environmental protection*

INTRODUCTION

In ensuring the safe operation of jet engines in all modes and in all conditions of application, fuels must be of safe quality. In addition to the general properties, characteristic of all liquid fuels, there are particularly strict requirements for a high degree of quality of specific properties. Such strict requirements are set and justified by the conditions of use of jet fuels, such as very high speeds and flight altitudes of jet aircraft, and they are affected by the most thermally loaded parts of the jet engine: combustion chamber, gas turbine, etc. as well as fuel installations. In addition to the above, there are other problems due to which the fuel for jet engines must meet certain requirements, such as: • to have the highest possible density and thermal power, because they depend on the range of aircraft with unchanged volume of fuel tank; • that it does not contain easily volatile fractions that would cause the formation of vapor plugs in installations and high fuel loss due to evaporation at high altitudes; • be easily refilled and flow continuously from the tank to the engine in all flight conditions of the aircraft; • not to freeze and not to emit hydrocarbon crystals at low temperatures (up to -50 ° C); • start the engine in all application conditions; • disperses well in all engine modes; • to have such a combustion rate that ensures the completion of the combustion process in the combustion chamber; • to burn completely, without the formation of sediment, soot and coke on the injector, combustion chamber, turbine and other engine parts; • to be thermally stable at elevated temperatures, in flight conditions at supersonic speeds and not to form solid sediments, etc. JET A-1 fuel is in use in our area, which is a kerosene fraction of oil with a boiling temperature in the temperature range from 170 ° C to 300 ° C. This jet fuel, in terms of its quality, meets the requirements of the military and civil aviation [1,2].

1. PHYSICAL AND CHEMICAL COMPOSITION OF JET FUELS

According to their chemical composition, jet fuels are complex mixtures and consist of four basic groups of hydrocarbons: paraffin, naphthenic, aromatic and olefin. Their content in fuel ranges from 98% to 99%, while the rest from 1% to 2% are non-hydrocarbon compounds: sulfur, nitrogen, oxygen and traces of various metals or compounds that contain metals. This composition of jet fuels is conditioned by strict requirements for the greatest possible thermal power and stability, and the least possible creation of soot, which is provided by paraffin and naphthenic hydrocarbons. Paraffinic and naphthenic hydrocarbons are the most common in jet fuels (about 70%). The content of aromatic hydrocarbons is less desirable because they have a lower thermal power (by about 10%), reduce the speed and completeness of combustion, increase the formation of soot, cause combustion of the combustion chamber and reduce thermal stability. Olefins are chemically unstable and prone to resin formation and impair the thermal stability of fuels. Their fuel content is limited to a maximum of 5% by volume. The low content of mercaptan sulfur (0.001% by weight) is strictly limited due to its pronounced corrosive aggressiveness [3,4].

1.1. Additives in jet fuel

Given the number and severity of the procedures used, it is often necessary and sometimes mandatory to use additives. Additives prevent the formation of harmful chemical species or improve fuel properties to prevent further engine wear. According to international standards, the use of the following additives is allowed in jet fuels [5]:
• Antioxidants - have a role to prevent gumming, usually based on alkylated phenols, eg AO-30, AO-31 or AO-37;

• Antistatic agents - to discharge static electricity and prevent sparks; Stadis 450, with dinonylnapium sulfonic acid (DINNSA); • Corrosion inhibitors, eg DCI-4A is used for civilian and military fuels, while DS-6A is used only for military fuels;
• Biocides - prevent the appearance of microbial compounds, ie bacteria and fungi that can be found in the composition of jet fuels (jet fuel pollutants). Currently, only two biocides are allowed for use, namely Kathon FP 1.5 Microbiocide and Biobor JF; • Metal deactivator - added in order to prevent harmful effects of metal surfaces on the thermal stability of the fuel. One of the permitted additives is N, N'-disalicylidene 1,2-propanediamine.

1.2. Some physical characteristics of Jet A-1 jet fuel

Table 1 shows some physical characteristics of jet fuel, JET A-1.

Table 1: Physical characteristics of jet fuel, JET A -1 [6]

Red. broj	*Fizičke karakteristike*	*Vrijednost*
1	**Tačka paljenja (PenskyMartens)**	min 38 °C
2	**Temperatura samostalnog paljenja**	210 °C
3	**Temperatura smrzavanja**	-47°C
4	**Maksimalna adijabatska temperature paljenja**	2,23 °C Open Air Burn temperature 1,03 °C
5	**Gustina na 15^0C**	0,804 kg/l
6	**Specifična energija**	42,80 MJ/kg ili 11,90 kWh/kg
7	**Energetska gustina**	34,7 MJ/l ili 9,6 kWh/l

2. MAKING FUEL MIXTURES AND COMBUSTING JET FUEL

As with other internal combustion engines, the combustion process is preceded by the formation of a fuel mixture in jet engines. The fuel mixture is continuously formed and burned, which is why the flow of air and fuel must be continuous, so as not to interrupt the combustion process. The air is introduced by a compressor, through a diffuser into the combustion chamber. The fuel, usually through injectors, is fed by a high-pressure pump directly into the combustion chamber. In order to effectively evaporate the liquid fuel entering the combustion chamber, it must be well dispersed. The spraying process takes place in several phases: 1) the passage of liquid fuel through the injector in the combustion chamber creates its curtain or spray jet; 2) the appearance of small waves and disturbances on the surface of the liquid as a consequence of previous turbulence and the influence of air on it;

3) formation of fine membranes of liquids under the influence of air pressure and surface tension forces; 4) crushing of membranes into separate droplets at the expense of surface tension of fuel; 5) further, even finer grinding of these drops. After entering the combustion chamber, the fuel mixture is ignited by an electric spark or special burners. The combustion process takes place in a very fast oxidation of fuel components with the release of a certain thermal energy. Figure 1 shows the appearance of the VIPER 632-46 engine.

Figure 1: Appearance of the VIPER 632 - 46 engine

After the initial ignition and combustion of the mixture, ie starting the engine, the process of so-called the actual combustion of the fuel mixture in the combustion chamber. The amount of air that enters the combustion chamber with fuel is several times greater than needed and is divided into primary and secondary air. The amount of primary air is 20 to 30% of the total amount and is introduced into the combustion chamber in several places. A secondary amount of air of 70 to 80% bypasses the outside of the front of the flame tube, cools it and enters through the openings and mixes with the rest of the fuel mixture and combustion products, impoverishing the mixture and cooling it. The fuel injected into the circulation zone, where the gases have a high temperature, evaporates quickly and burns in the front part of the chamber, depending on the degree of mixing with the air in the vortex layer. Prolongation of combustion of the mixture, with further movement through the flame tube, is possible by adding secondary air which impoverishes the mixture. Gases and particles produced by the combustion of aircraft fuel are: water vapor (H_2O), carbon dioxide, CO_2, nitrogen monoxide, NO, nitrogen dioxide, NO_2 (NO and NO_2 are collectively referred to as NO_x), sulfur oxides, SO_x and soot. These elements of the combustion process of propellant are mainly retained in the part of the troposphere that is characterized by high humidity and slightly higher temperature, in whose lower layers, the atmosphere usually warms and heating decreases with increasing altitude.

3. LUBRICANTS FOR JET ENGINES

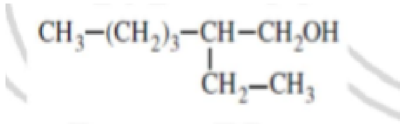
It is known that jet engines are, in principle, simpler than piston engines in terms of their complexity and construction, and are therefore simpler when lubricating lubricants are applied. Since there is no fuel in the combustion chamber

moving parts, and the lubricant is not directly exposed to combustion temperatures. As the compressor and turbine are the main moving parts in constant rotation, problems with dynamic loading due to return rotations of the elements are avoided. But even so, lubricants continue to face serious challenges, the biggest challenge being heat. Modern engine housings achieve lubricant temperatures in the range between 80 ° C and 100 ° C, while during purification this temperature rises to approximately 190 ° C, with exposure to temperatures along the metal wall in the chamber bearing up to 300

° C and 400 ° C [4.5]. Combining this with the fact and the tendency to make aircraft in flight as durable as possible, to reduce maintenance costs and extend the time between major overhauls, currently more than 40,000 operating hours for some civilian engines, then it is clear how lubricants must be stable over a long period of time. There is a problem related to the difficulty of the lubricant to remain functional for so long. Lubricants wear out during operation, they need to be replaced with fresh lubricants. There are no products that would remove the sediment caused by the combustion of lubricants (the problem of the regular formation of deposits of coke deposits due to high temperatures during engine operation). Any sediment created must be removed, to prevent clogging. The lubricant continues to play an important role in reducing the formation of deposits and therefore, the possibility of efficient removal of the already formed deposits must be achieved. The thermal stability of turbine lubricants is probably the biggest challenge for both lubricant manufacturers and jet engine designers [5].

3.1. Composition and properties of lubricants for jet engines

In the production of lubricating oils in the aerospace industry, esters, ie di-ester based lubricants based on di-basic acids, such as [4]: sebacic acid, HOOC– (CH2) 8–, have proven to be the most efficient. COOH; azelaic acid, HOOC– (CH2) 7 - COOH and adipic acid, HOOC– (CH2) 4 – COOH. These acids, in reaction with alcohols, form diesters. The choice of both acid and alcohol has a significant impact on the properties of the finished product. For example, more di-acid chains improve the viscosity index but reduce the pour point. Of the alcohols, octanol, CH3 - (CH2) 7 - OH, is commonly used. If noctanol is used, it causes the temperature of the diester to cool to an unacceptable level. However, the use of 2-ethyl hexanol isomers, Figure 2:

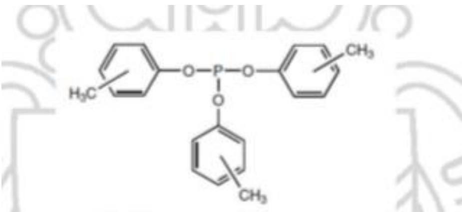


Slika 2: 2- etil heksanol

It gives a significant reduction in the pour point, while maintaining an acceptable viscosity index (usually used in the production of diester base oils) [4]. The properties of base oils are improved by adding additives to the finished product. In addition to polyglycol thickener, which is used in 7.5 cSt diester - base lubricants, polyol is also used for most types. The resulting di-ester lubricants are suitable for maximum tank oil temperatures up to 149 ° C and bearing temperatures up to 204 ° C. In jet engines, the lubricant additives most commonly used against oxidation are phenyl-α-naphthylamine, PAN, octylphenyl-α-naphthylamine, OPAN and dioctiphenylamine, DODPA and their derivatives. Phenothiazine is a common antioxidant used in early versions of ester based turbine lubricants, but although it is effective in preventing oxidation, I the lubricant oxidizes after a long time.

Due to the formation of oxidized particles (the main limiting factor for the engine manufacturer), the use of phenothiazines was stopped. Phenyl-β-naphthylamine has been shown to be a good lubricant, but its use is prohibited when an extremely harmful effect on the environment is detected [4]. The optimal efficiency of lubricants for jet engines, in terms of achieving a synergistic effect, is given by two anti-oxidants (greater safety at a given concentration together than individually). It is a combination of oligomeric and monomeric amines as antioxidants. Another innovation is the application of the monomeric antioxidants that make up the oligomers during oxidation, thus extending the duration of the anti-oxidative properties of the lubricant. One major drawback of modern antioxidant combinations is their tendency to be aggressive towards elastomers. Lubricants are also used to reduce the wear of aircraft parts, with tricresyl phosphate, TCP, usually used in concentrations between 1 and 3%.

TCP reacts with the surface of the metal, forming a chemical absorption layer that protects the elements from friction with each other. The chemical formula of this compound is shown in Figure 3:

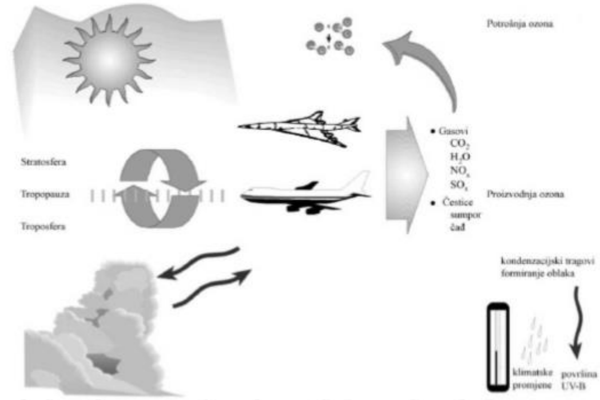


Slika 3: Trikrezil fosfat, TCP [4]

In the case of extreme pressure conditions, such as in engine transmissions and helicopters, lubricants containing phosphate salts with amine additives can be used. Although this improves the ability of the lubricant, in this way the lubricant can be made more aggressive towards certain types of elastomers, especially the silicone material (increasing the coking ability of the lubricant). Another disadvantage is that in the presence of water, this type of additive reacts with the unprotected magnesium alloy found on the surfaces of the engine interior. If the system is dry or the magnesium alloys on the surfaces are sufficiently well protected by an epoxy coating, then the reaction does not take place [4].

4. IMPACT OF FUEL AND LUBRICANTS IN AVIATION ON THE ENVIRONMENT

Oil and its derivatives, including fuels and lubricants used in aviation, are the basis of modern industrial development, but unfortunately, at the same time, fundamental polluters of the environment. Environmental pollution with oil and derivatives is the most widespread and widespread, starting from individual human influences, as users of motor vehicles and other mechanical systems, to the continuous influence of all branches of industry and all forms of economic activities. According to all previous research results, all types of lubricants, fresh, used or waste oils, are considered environmental pollutants. All lubricants, especially waste, destroy the microflora of the soil and make it infertile for a long time, because they are biologically difficult and slow to decompose. Even in very small concentrations, they make water unusable for drinking. When it comes to waste oils, the degree of danger increases depending on the length of use and the severity of the working conditions [7]. During the flight of the aircraft, the products of fuel combustion are dangerous pollutants of the atmosphere, Figure 4.



Slika 4: Vazduhoplovstvo u atmosferi [1]

Most aircraft fly in the troposphere and lower stratosphere, that is, at altitudes between 9 and 20 kilometers above the earth's surface. Today, commercial passenger planes are exclusively of the subsonic type and fly at altitudes of up to 13 kilometers. Most emissions of exhaust gases and particles take place at altitudes up to 13 kilometers above the earth's surface. Part of the emission is also released on the surface of the earth (at airports during take-off and landing) [1,2].

Air pollution includes the presence of one or more substances such as: aerosols (dust, smoke, fog), gases and vapors of such importance and in such concentrations that they may be harmful to human and / or animal life and health. They can also negatively affect the plant world. Although the problem of air pollution and the negative effects of pollutants on humans has existed for several hundred years, no special attention has been paid to it, until several catastrophic examples of such pollution caused the issue to be highlighted as one of today's important public health problems [7,8]. Some of the catastrophic examples have resulted in acute illness and even deaths of large numbers of the population in a short time interval in a limited area.

5. CONCLUSION

Fuels and lubricants used in aviation differ from fuels and lubricants used in other forms of transport, primarily due to different physical forces, atmospheric conditions and engine and helicopter engine designs, but also due to the need to achieve maximum safety and performance. and all in order to minimize the possibility of any error or malfunction. Depending on the type of engine in the plane, different fuels and different lubricants are used. For the past few decades, jet engines have been using Jet A-1 jet fuel. According to the chemical composition, jet fuel is a complex mixture of four basic groups of hydrocarbons: paraffin, naphthenic, aromatic and olefin. Their content in the fuel ranges from 98% to 99%, while the rest from 1% to 2% are non-hydrocarbon compounds S, N, O and traces of various metals or compounds containing metals. Gases and particles produced by the combustion of aircraft fuel are: water vapor (H2O), carbon dioxide, CO2, nitrogen monoxide, NO, nitrogen dioxide, NO2 (NO and NO2 are collectively referred to as NOx), sulfur oxides, SOx and soot. Lubricants are facing today, and will continue to face serious challenges in the future, the biggest challenge being heat. Modern engine housings reach lubricant temperatures between 80 and 100 ° C, while during cleaning this temperature rises to approximately 190 ° C, with additional exposure to temperatures along the metal wall of the combustion chamber bearing, up to 300 and 400 ° C. The significant impact of in-flight combustion exhaust gases on the environment, which is estimated to be increasing daily, is not to be overlooked. Greenhouse gas emissions, but also the presence of environmentally unacceptable substances in certain lubricants, is a significant environmental problem. Therefore, the production of biodiesel suitable for airplanes and helicopters is expected to significantly improve the problem of fuel consumption and environmental impact in the future.

6. LITERATURE

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