Impact of biofuel addition into conventional jet fuel

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***Abstract* — This article deals with the use of biofuel addition into conventional jet fuel for aviation jet engine propulsion. A first part of the carried out research examines a possibility of the use a mixture of FAME (Fatty Acid Methyl Ester) and Jet A-1 at various concentrations. Experimental research involves a miscibility of these fuels, an impact of mixtures on the operational properties of a small experimental jet engine MPM-20 and an impact on rubber seals used in fuel systems. A second part of the research is focused on the use of ethanol in a mixture with Jet A-1 and its impact on the operational properties of MPM-20 engine. Finally, the benefits and shortcomings of the use of selected biofuels are summarized on the basis of carried out experiments.**

***Index Terms* — Biofuel, FAME, Oil based biofuel, Alcohol based biofuel.**

I. Introduction

Air transport is one of the fastest growing modes of transport. Its growth can be predicted at 5% per year, which puts increased demand for fuels [1]. At present, the most used fuel for aviation jet engines is Jet A-1, which is made from crude oil. Due to the gradual depletion of crude oil resources and global agreements limiting emissions production [2,3,4], new types of fuels need to be looked for. Although the efficiency of jet engines will be increased by 15 to 20% in the next period, it will not be enough and it will be required continue increasing amount of fuel [5]. New fuels must be sustainable; their cost must be at an acceptable level and should have environmental benefits.

Expedience of the use liquid fuels results from their liquid state. The use of liquid fuels is empirically verified and does not require drastic changes in the construction of aircraft, jet engines and fuel delivery infrastructure. Liquid fuels for use in jet engines include Jet A-1, synthetic fuels and biofuels. Synthetic fuels are not a long-term alternative; they can shortly help reduce pressure on oil derived fuels [6]. The use of synthetic fuels and biofuels is counted in the form of a certain addition into Jet A-1, their use in pure form is questionable.

II. Biofuels

Biofuels produced from local sources could solve problems related to the decrease in crude oil reserves. In general, biofuels are renewable sources of energy that have the potential to achieve a zero carbon footprint [7]. The zero carbon footprint reflects the fact that the human activity does not cause any new carbon dioxide emissions and does not contribute to the global warming.

III. Oil Based Biofuels

Basic feedstock for the production of these biofuels is oil obtained by various processes from predominantly food crops such as palm oil, rapeseed, soybean, nuts and many others. This oil is further processed to the required fuel. The problem arises in the cultivation of plants that require huge amounts of agricultural land. To ensure sufficient capacity of the farm land, is realized deforestation and burn practices, which will ultimately lead to a worsening of the global warming. Simultaneously repeated cultivation of monocultures and agricultural interventions cause completely land depreciation. For these reasons, it is necessary to focus on the long-term sustainability of crop cultivation for biofuel production.

In India, a palm oil is currently useful feedstock for oil-based biofuel production. In Brazil is babassu nut oil obtained from native Brazilian palm, in Europe is rapeseed oil and in US is soybean oil. The extracted oil is transesterified to FAME (Fatty Acid Methyl Ester), the properties of which are comparable with diesel fuel. Therefore, its primary use is to replace diesel fuel for diesel engines. FAME is nontoxic, contains no heavy metals or no harmful substances.

In general, developed countries are unable to produce enough conventional crops for biofuel production. On the other hand, some countries in the world have the potential in regard to the enormous areas of arable land and low fuel demand. These countries are capable to be completely self-sufficient in the biofuel production and in replacing conventional fuels.

IV. Experimental Research of FAME for Jet Engine Application

The research realized at the Faculty of Aeronautics in Kosice was focused on the possibility of the use FAME, made mainly from rapeseed oil, and Jet A-1 mixture for aviation jet engine propulsion. Three problem areas have been solved.

The first tackled problem was the miscibility of FAME and Jet A-1. It has been found that all mixtures up to 90% of FAME share are homogeneous and even after year the components do not tend to separate.

The second part of the experimental study had aim to assess the impact of the use FAME and Jet A-1 mixture to the operational properties of an experimental engine MPM-20 (Fig. 1). The MPM-20 is the small single-shaft turbojet engine that was developed by modification of a turbine starter motor TS-20. To perform the experiments, the MPM-20 jet engine was set up at reduced regime. The MPM-20 jet engine is equipped with sensors that sense the basic thermodynamic parameters of the engine and other selected parameters that characterize its operation. Various mixtures were tested with 0%, 10%, 20%, 30% and 40% of FAME share in the mixture. The use of mixture with 40% of FAME share has been boundary. The greater proportion of FAME has caused a lower quality of fuel spraying in the combustion chamber resulting in worse evaporation in the combustion chamber. Ultimately it has caused the impossibility to ignite the mixture by the MPM-20 ignition system. Starting the engine with 45% and 50% of FAME share has been possible only with the heated engine from previous operation. The realized measurements have shown that FAME addition impacts the parameters of the experimental engine MPM-20 only to a small extent, because FAME and Jet A-1 have only a small difference in energy density. Substantial influence has been observed only during start up. As representative courses of the MPM-20 jet engine parameters depending on the FAME share in the mixture have been selected the changes in engine speed and engine thrust (Fig. 2, Fig. 3), the fuel volume flow rate into the engine during experiments was almost the same (Fig. 4).

The last problem that had to be experimentally demonstrated was the negative impact of FAME on rubber seals used in fuel systems of jet engines. The experiments were aimed to evaluation of the change in volume of rubber O-rings depending on the proportion of FAME in the mixture and exposure time. The results of these experiments are shown in the graph (Fig. 5). It can be concluded that the increasing share of FAME in the mixture and the prolonging duration of action have caused more intensive etching, swelling, loss of strength and sealing function. When using these biofuels in aviation jet engines, it will be necessary to replace rubber seals by seals made from different materials.

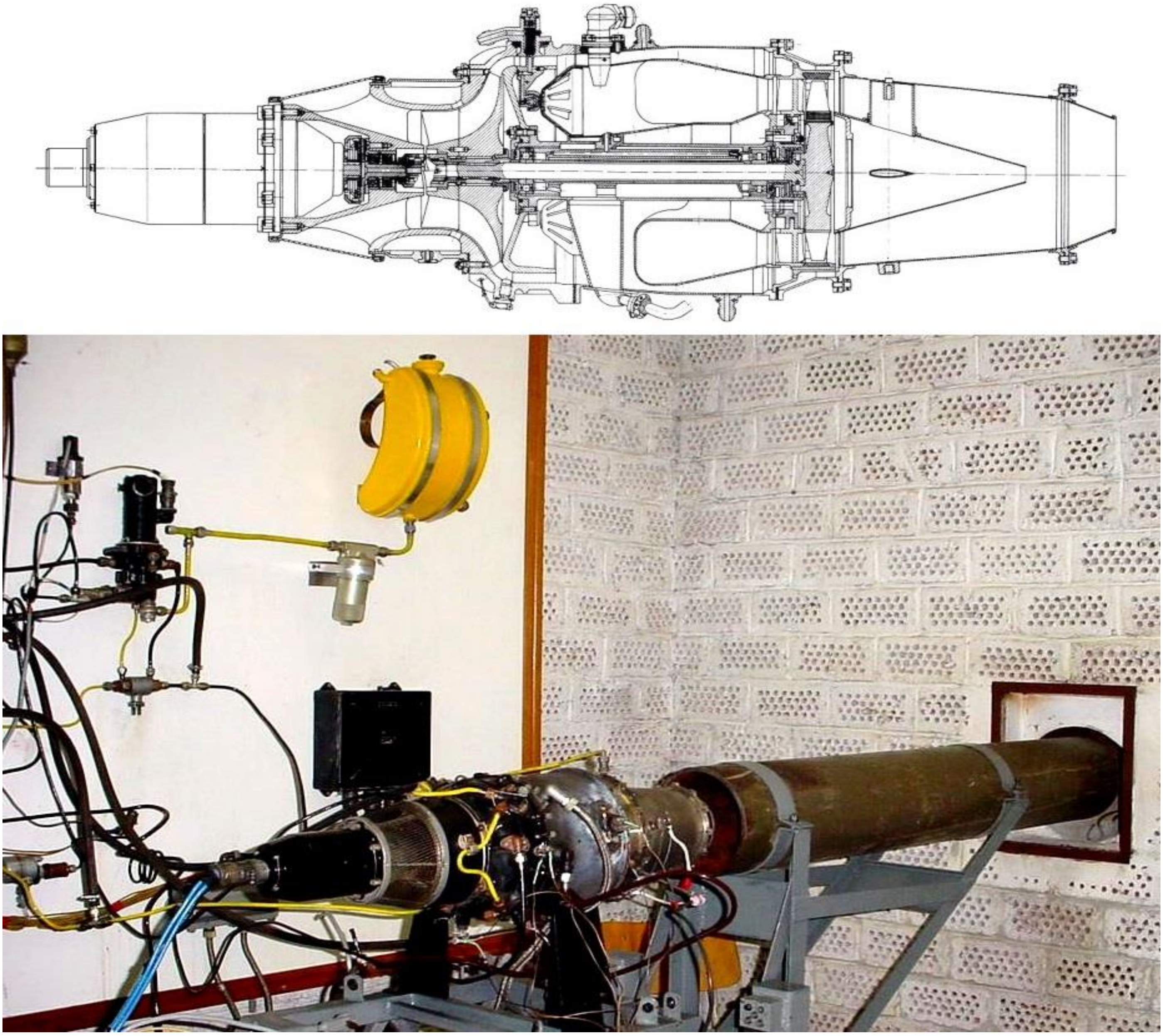

Figure 1. Jet Engine MPM-20

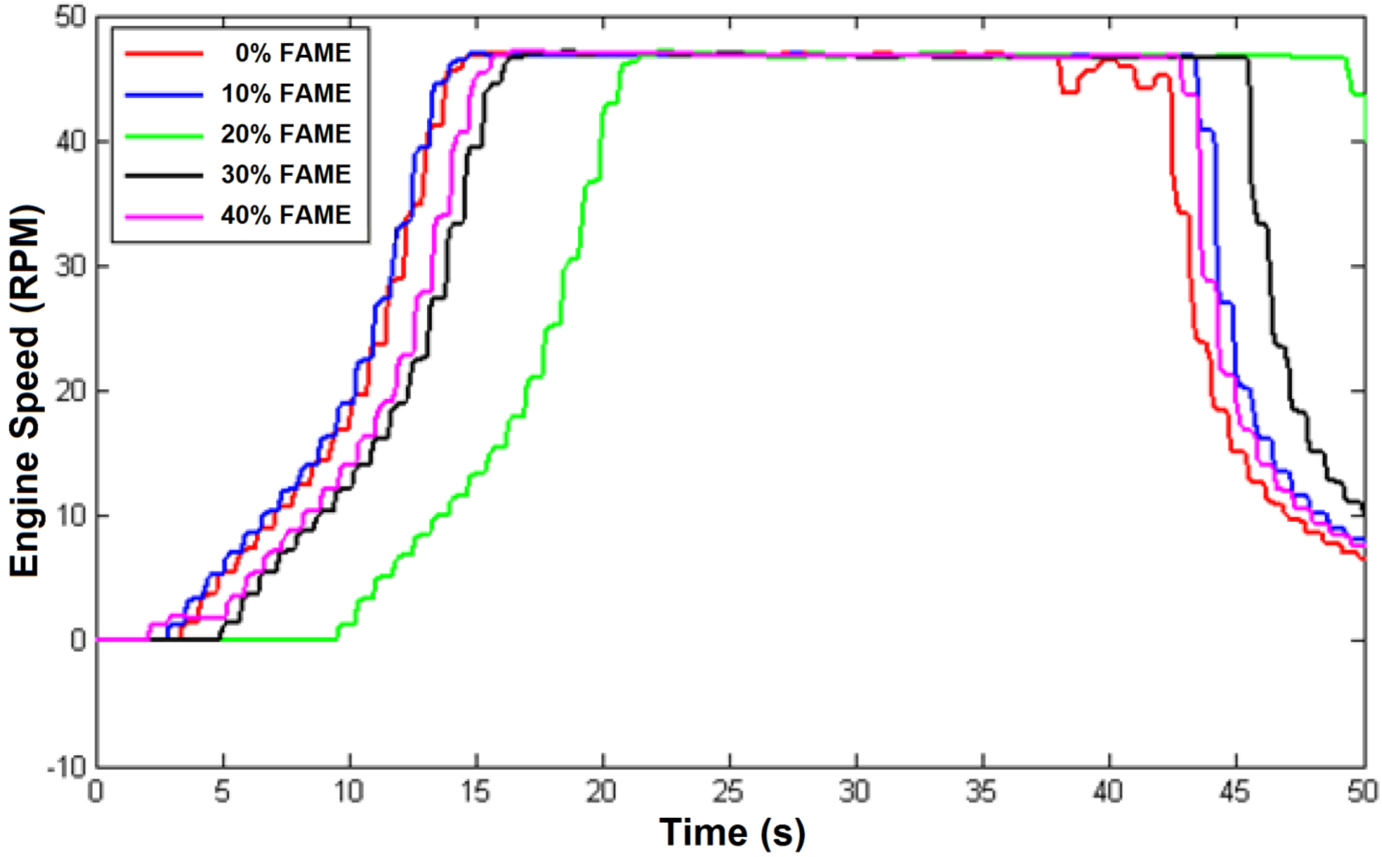

Figure 2. Effect on Engine Speed by using FAME

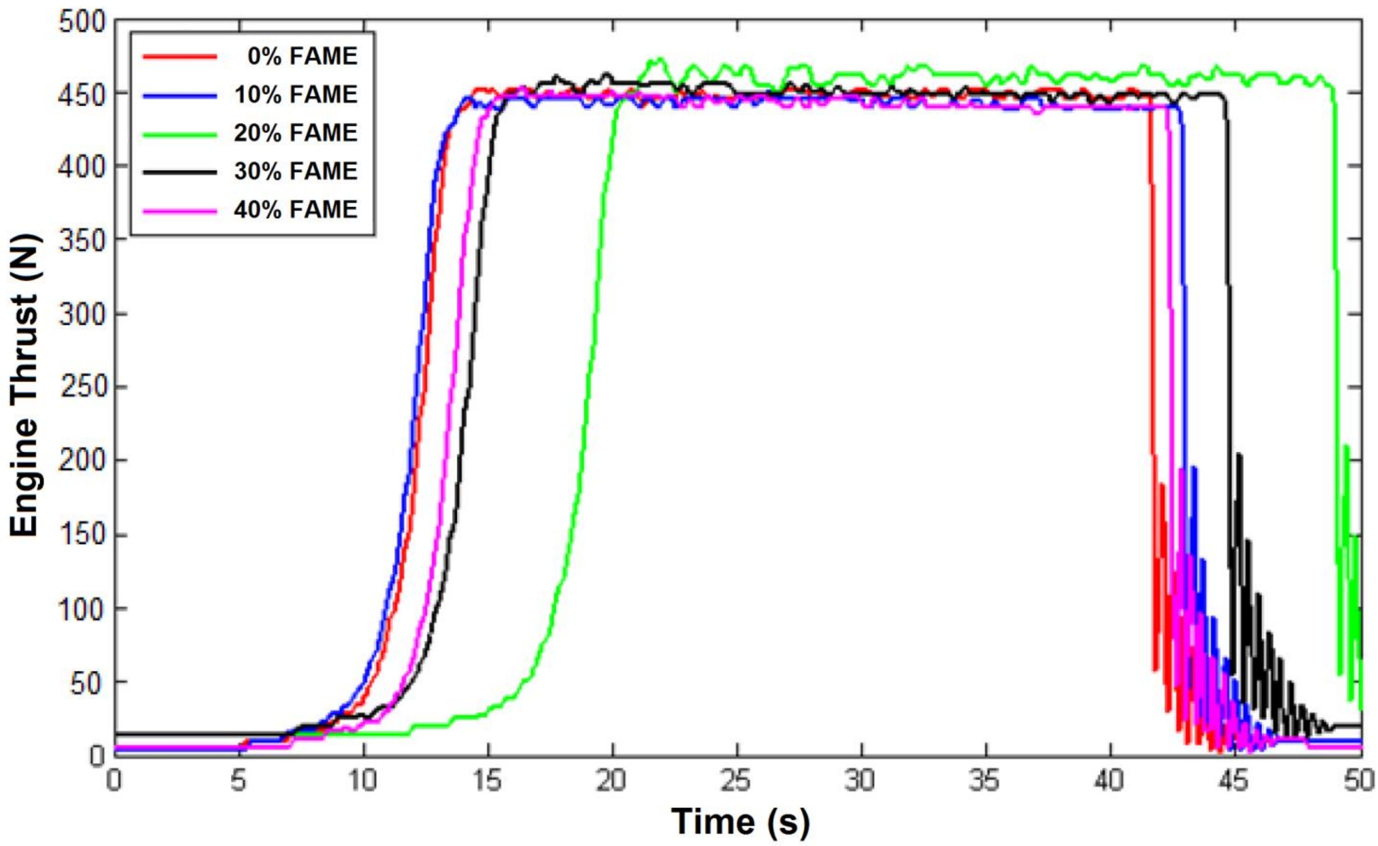

Figure 3. Effect on Engine Thrust by using FAME

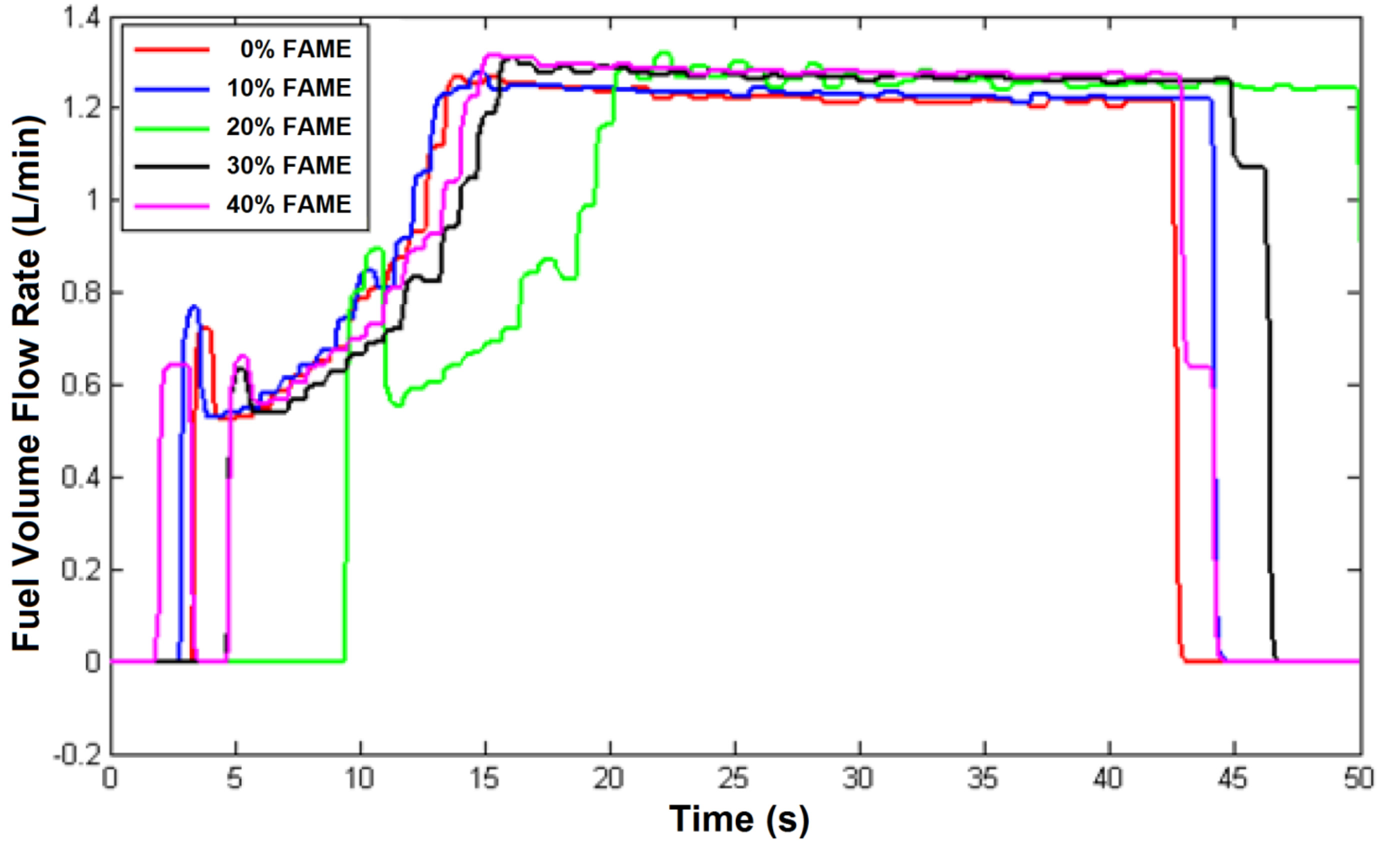

Figure 4. Fuel Volume Flow Rate by using FAME

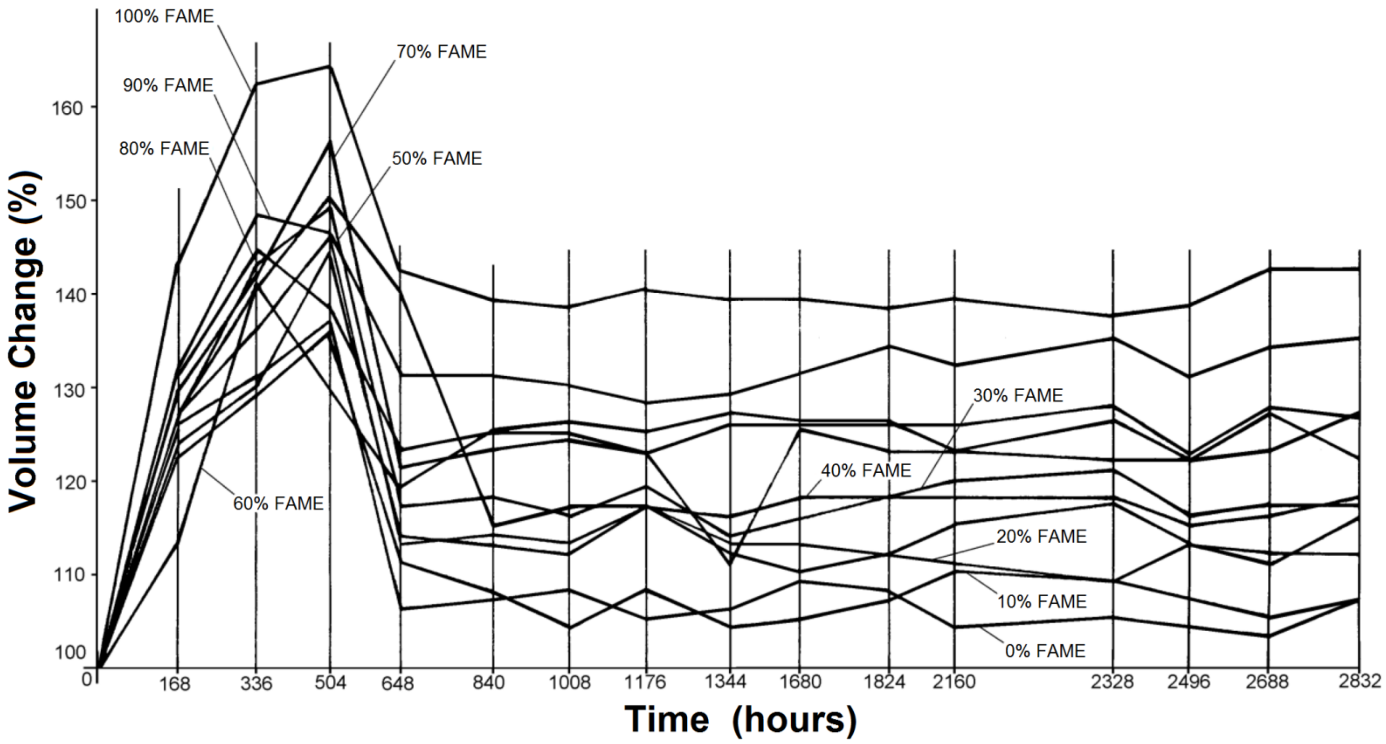

Figure 5. Effect on Rubber Seal by using FAME

V. Alcohol Based Biofuels

Alcohol-based biofuels include ethanol and methanol. In the world, ethanol is commonly used as a substitute for gasoline. Suitable raw materials for the production of ethanol are agricultural crops such as grain, potatoes, corn, sugar cane, sugar beet, and the like. Compared to ethanol, methanol has a wider potential in terms of raw materials. Methanol is most often produced from wood and other biomass, so there is no need for arable land for its production. In addition, methanol can also be produced from coal and natural gas. The advantage of using alcohol-based biofuels is improved combustion process and reduction the production of harmful emissions [8,9]. On the other hand, their energy density is significantly lower than the energy density of Jet A-1, which will require larger volumes of fuel tanks.

VI. Experimental Research of Ethanol for Jet Engine Application

Further research at the Faculty of Aeronautics was carried out with the use of an alcohol-based biofuel, concretely 99.9% ethanol. The experiments were focused on the impact of the use a mixture of ethanol and Jet A-1 on the operational properties of the experimental engine MPM-20. Five fuel mixtures were used with 0%, 10%, 20%, 30% and 35% of ethanol share. At 40% ethanol content, it has not reached the steady engine operation. This proportion of ethanol in the mixture has caused approximately the half of the required operating speed in compared with the use of pure Jet A-1. To display the changes has been selected the engine speed of the MPM-20 engine (Fig. 6), the fuel volume flow rate was set to the same value (Fig. 7). The miscibility of ethanol and Jet A-1 had been trouble free. Negative effect of ethanol on fuel system materials has not been observed.

On the basis of conducted experiments with ethanol, it can be stated that the increasing proportion of ethanol in the mixture results in a reduction in engine thrust, engine temperatures and pressures. Decreasing the values of these parameters is due to the lower energy density of ethanol as compared to Jet A-1. To maintain the required engine parameters, it would be necessary to make changes in the fuel control system of the engine.

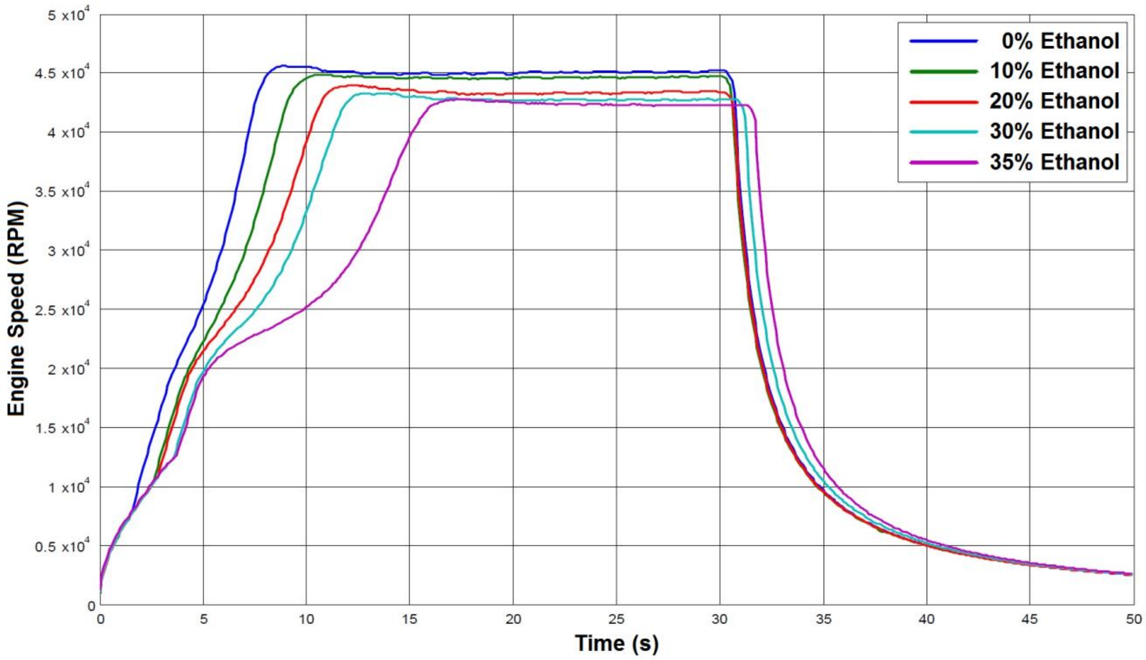

Figure 6. Effect on Engine Speed by using Ethanol

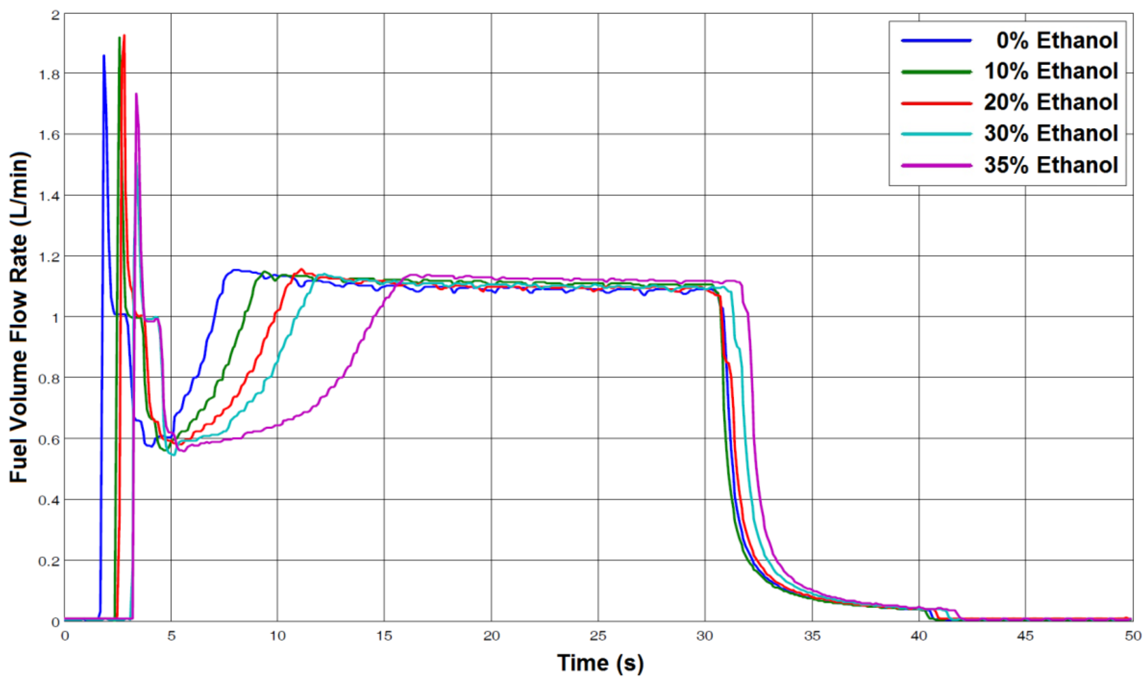

Figure 7. Fuel Volume Flow Rate by using Ethanol

VII. Conclusion

The use of biofuels in aviation can bring benefits in the form of reducing the harmful emissions, mainly carbon dioxide, thus eliminating the impact on the global warming and human health. Their use also reduces the dependence of countries on crude oil. On the basis of the realized research, it is possible to state the positives and negatives of the use of biofuel and Jet A-1 mixtures as fuel for the jet engineMPM-20. The use of FAME is possible until the 40% FAME concentration in the mixture. Its use has very little effect on changing the jet engine parameters, does not require changes in jet engine construction and is trouble free miscible with Jet A-1. On the other hand, FAME has the destructive effect on rubber seals used in the fuel system, therefore rubber material must be replaced by other types of material during long-term use. The use of ethanol has resulted in the reduction of temperatures and pressures in the jet engine and in improvements in fuel properties at jet engine start up. Negative is decreasing the jet engine power with the increasing proportion of ethanol in the mixture. Mixtures with more than 35% ethanol concentration are not applicable. Because ethanol has the lower energy content, more fuel on aircraft board is needed. In addition, the use of ethanol reduces the lubricating properties of the fuel.

Still, it is necessary to look for other oil sources with much higher yield as has traditional agricultural crops. One of the promising bio-feed stocks are microalgae [10]. The second path of development leads to the use of gaseous fuels with necessary dramatic changes in aircraft construction [11]. At the same time, the use of new fuel types will require changes in the entire fuel supply infrastructure. There are still many obstacles that need to be overcome, which opens the way for further research in this area.

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