UDC 341.241

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Use of ASTM Certified Alternative Jet Fuels in Aviation Gas Turbine Engines

Increasing fuel consumption worldwide and limited fuel resources have pushed researchers to find alternative jet fuel sources. Blending alternative jet fuels with conventional jet fuels was first approved by ASTM in 2009. In this short review, the use of today's ASTM-certified alternative jet fuels in gas turbines has been examined.

Introduction

The world population is increasing. Increasing world population leads to an increase in energy demand. The aviation sector is also growing every year with a similar trend to the increasing world population. The irresistible growth of the aviation industry increases the number of aircraft and also increases the amount of fuel consumed. Aircrafts use petroleum-derived (fossil fuel) conventional jet fuels (such as Jet A-1, Jet A, and JP-8). The need for renewable and sustainable alternative jet fuels is increasing day by day as fossil fuel resources are limited and gradually decreasing. Moreover, the greenhouse gas effect, which increases due to carbon emissions as a result of the burning of fossil fuels, causes adverse effects on the atmosphere of the world we live in, leading to climate change. Considering the adverse effects of fossil-derived fuels on climate change, the need for renewable and sustainable jet fuels is inevitable. It is very critical to use renewable and sustainable fuels, grouped as carbon neutral, in aviation in order to prevent the effect of greenhouse gas and mitigate the impacts of climate change.

Alternative jet fuels can be used as jet fuel in commercial aviation after approval by the American Society for Testing and Materials (ASTM). Alternative jet fuels that meet ASTM specifications such as flash point (ASTM D93), freezing point (ASTM D2386), density (ASTM D1298), kinematic viscosity (ASTM D445), lower calorific value (ASTM D2015), and aromatics (ASTM D1319) can be used in commercial aviation. According to ASTM D7566 specification, alternative jet fuels can be blended with conventional jet fuels (Jet A-1) in different proportions depending on the raw material source and conversion method. Although there are different percentages for each alternative jet fuel, this blending ratio is limited up to a maximum of 50%.

The Fischer-Tropsch (FT) pathway was the first jet fuel production process approved by ASTM in 2009. The fuels produced by the FT Synthetic Paraffinic Kerosene (FT-SPK) pathway can be blended with conventional jet fuels at a rate of 50% and used in commercial aviation. Another alternative jet fuel type produced by the FT method is FT Paraffinic Kerosene Aromatics (FT-SPK/A). The FT-SPK/A method was approved by ASTM in 2015 and it can be blended with conventional jet fuels at a rate of 50% [1,2].

Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA-SPK) is the second alternative jet fuel production pathway certified by ASTM for use in commercial aviation. Alternative jet fuels produced by the HEFA pathway since 2011 can be used by blending with conventional jet fuels at a rate of 50% [1,2].

The Synthetic Isoparaffins (SIP) pathway was certified by ASTM in 2014. Alternative jet fuels produced by the SIP pathway are allowed to be blended with conventional jet fuels for up to 10% [1,2].

The Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK) pathway has been certified by ASTM since 2016. Alternative jet fuel produced by the ATJ-SPK method can be blended with conventional jet fuel for up to 30 [1,2].

The Catalytic Hydrothermolysis (CH) pathway is ASTM certified as of 2020. Alternative jet fuel produced by the CH pathway can be blended with conventional jet fuels for up to 50% [1,2].

Hydroprocessed Hydrocarbons, Esters, and Fatty Acids Synthetic Paraffinic Kerosene (HHC-SPK or HC-HEFA-SPK) pathway have been approved by ASTM since 2020. Alternative jet fuels produced by the HC-HEFA-SPK pathway can be used by blending with conventional jet fuels at a rate of 10% [3,4].

Table 1.

Comparison of the properties of conventional and alternative jet fuels [5-13]

Properties	Jet A-1	FT-SPK (CtL)	HEFA-SPK	SIP	FT-SPK/A	ATJ-SPK	CH	HC-HEFA-SPK
Flash point (°C)	42.0	46.0	40.5-53	107.5	>38	47.5	42.5	>38
Freezing point (°C)	-47	<-80	-54.4	<-80	<-40	<-80	-41.3	<-40
Density at 15°C (kg/m^3)	0.775–0.840	730 – 770	730 – 770	773.1	755-800	757.1	805.2	730-800
Kinematic viscosity at -20 °C (mm^2/s)	<8	3.71	4.801	14.13	3.421	4.795	3.977	-
LHV (MJ/kg)	43.2	>42.8	44.154	44	>42.8	>42.8	43.202	>42.8
Sulfur (vol.%)	<0.3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Aromatic (vol.%)	18.8	<0.5	<0.5	<0.5	<20	<0.5	19.7	<0.5
Lubricity (mm)	<0.85	0.780	0.906	0.562	-	0.839	0.570	-

Emission characteristics of alternative jet fuels

Biofuels are classified as carbon neutral. For this reason, the use of biofuels as aircraft fuels can be more advantageous to climate change compared to conventional petroleum-derived jet fuels. Emissions are not an ASTM fuel certification process. For this reason, the investigation of emissions released into the atmosphere by the combustion of alternative jet fuels has been an attractive research topic.

Wahl et al. [14] carried out emission analyses of FT-SPK/Jet A-1 blended fuels in a turbofan engine. 10%, 20%, 30%, 40%, and 50% FT-SPK were added to Jet A-1 and the results were compared with pure Jet A-1. In the tests, CO, CO2, NO, NO2, SO2, and particle size and number were measured. According to the results, as the FT-SPK additive in the blended fuels increased, the particle mass and number decreased significantly. Also, the particle diameter decreased. Other gas emissions showed little improvement in some flight phases. In particular, NO emissions decreased significantly during the climb and take-off phases of the flight.

In another study [2] in which emission analyses were performed, 10% and 20% SIP were added to Jet A-1 fuel and the emissions resulting from combustion were analyzed. CO, NOx, and particulate emissions were measured in the tests. The results were compared with the reference Jet A-1. While the addition of SIP to jet fuel had no effect on CO emissions, there was a slight reduction in NOx emission, although not consistent in all phases of flight. However, there was a noticeable reduction in particulate emissions. Although there is a significant decrease in the total mass of particulate emissions, the surface of particulate emissions, and number of particulate emissions, and a decrease in the average particle diameter, this is not the case for all phases of flight.

Gawron and Białecki [15] conducted emission tests of HEFA/Jet A-1 blended fuel in a micro gas turbine. While HEFA/Jet A-1 blended fuel and pure jet fuel had similar CO emission values, CO2 and NOx emissions of the blended fuel were measured less.

According to results compiled from a review [16], alternative jet fuels have little or no effect on CO, CO2, and NOx emissions. However, it was emphasized that especially FT-SPK, HEFA, and SIP alternative jet fuels significantly reduced particulate emissions.

Corporan et al. [17] reported that the NOx and CO2 emission values of FT-SPK and HEFA fuels were similar to those of JP-8 fuels, while CO and UHC emissions were 10-25% less than JP-8 fuels. It was emphasized that the absence of aromatics in FT-SPK and HEFA caused a decrease in CO and UHC emissions.

Gaspar and Sousa [18] tested alternative jet fuels in a turbofan engine. As a result of the tests, it was reported that CO and NOx emissions decreased when alternative jet fuels were used, while UHC emissions increased. In addition, it was reported that PM emissions decreased by 30-70%.

Conclusions

As a result of the combustion of conventional jet fuels, high amounts of CO2 are released into the atmosphere. CO2 released into the atmosphere causes climate change by causing the greenhouse gas effect. For this reason, it is of great importance to use renewable and sustainable alternative jet fuels, known as carbon neutral, in aviation sector.

In this short review, the emission values of alternative jet fuels are compared with conventional jet fuels. According to the results, there is a significant correlation between the aromatic content and soot emissions of alternative jet fuels. Moreover, alternative jet fuels release emissions similar to or lower than conventional jet fuels in terms of gaseous (CO, CO2, NOx, and UHC) emissions. As a result, alternative jet fuels have lower emissions than conventional jet fuels. In addition, alternative jet fuels can contribute to the improvement of air quality as they reduce soot emissions.

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