Role of Alternative Fuels in Enhancing Combustion Efficiency in Aero Gas Turbines

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INTRODUCTION:

Aviation today is responsible for 1.6% of global greenhouse gas emissions, which includes 2-3% of anthropogenic CO_2 emissions. Conventional aviation kerosene also known as Jet-A, contributes significantly to CO_2 and NO_x emissions. Due to the rapid decline in fossil fuels, attention has shifted towards exploring the use of alternative fuels to enhance combustion in Aero gas turbines for the future. The environmental footprint of Aero gas turbines stems primarily from carbon emissions and air pollutants. shift towards alternative and sustainable fuels to ensure cleaner and more efficient aviation.

OBJECTIVES:

To minimize emissions from turbines, the improvement of combustion efficiency is important as it reduces the release of unburned hydrocarbons and optimizes the fuel-to-energy conversion. This decreases greenhouse gas emissions and lowers specific fuel consumption. Achieving higher combustion efficiency directly supports environmental sustainability goals while maintaining the high thrust and reliability required in aviation applications. This study explores the environmental effects of using alternative fuels in aero gas turbines while advancing combustion efficiency with minimal fuel loss. Correct use of fuel can help the Aviation industry achieve a carbon-neutral position.

METHOD:

Thermal efficiency is approximated based on the energy output relative to the energy content of the fuel. Combustion efficiency is calculated using :

Combustion efficiency = [Actual Heat Output / Theoretical Heat Input]

Where, Actual Heat Output is determined from exhaust gas temperatures and airflow rates and Theoretical Heat Input is based on the calorific value of each fuel.

CO_2, CO, and NOx concentrations are quantified using gas analysers. Experimental setups include test combustors, micro-turbines, and engine rigs, instrumented with thermocouples, emission analyzers, and flow meters

RESULTS:

Hydrocarbons as alternative fuels are today understood. Their contents result in less NO_x production, hence less harm to the environment. However, these fuels alone are insufficient and must be combined with certain hydrocarbons to deliver the required energy levels.. Therefore, the use of different biofuels in gas turbines has been discovered such as biodiesel, bio-ethanol, bio-methanol, pyrolysis oil, biogas, etc.

Methanol is an ideal alternative fuel for aero gas turbines to reduce CO_2 and NO_x emissions. Biogas can be produced from organic waste. Hydrogen as an alternative fuel is usually selected as it has a high specific energy density and can be produced via gasification of biomass followed by reforming of the syngas.. Since it has the potential to improve fuel efficiency, and increase range while significantly decreasing greenhouse gases such as carbon monoxide, hydrogen can be used as an alternative fuel to boost combustion efficiency.

eMethanol is a carbon-neutral, energy-dense liquid fuel produced from hydrogen and captured carbon dioxide. No SO2 emissions and low smoke Performance improvement. It increases power upto 10% due to higher mass flow and is less toxic, mutagenic and carcinogenic material. Small-turbine tests with biodiesel-derived esters show higher fuel flow and lower emissions. According to the experiments conducted, a GT85 microturbine burning **80%** olive oil methyl ester (OME) with **20%** Jet-A has been observed an **8.7%** drop in net thermal efficiency and a **13%** rise in TSFC at high load, but achieved much lower exhaust pollutants as CO fell approximately **29%** and NO_x **34%** (both relative to pure Jet-A).

Hydrogen combustion yields no CO or HC (no carbon in the fuel), so CO = 0 for any hydrogen blend. Experiments confirm that a modified 100 kW microturbine burning 100% H_2 produced zero CO and carbon emissions, with NO_x controlled to below 25 ppm. The data recorded is 75% reduction in CO_2 emissions per passenger kilometre. 90% reduction in NO_x emissions. 65% reduction of the perceived noise.

CONCLUSIONS:

In brief, merging sustainable fuel advancements with advanced combustion technologies provides an actionable blueprint for environmental transformation in aviation. Utilizing engineered biofuel blends and innovative e-fuels in tandem with ongoing combustor and injection technology improvements equips the aerospace industry to transition aero gas turbines toward carbon-neutral operation. This strategy safeguards the defining qualities of modern flight thrust, reliability, and efficiency while significantly cutting reliance on finite fossil kerosene fuels. This approach lays the foundation for a sustainable and responsible future in global air transportation.

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