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Experimental Study of Jet Propulsion Efficiency Using Novel Fuels

Noura Haddad*

Department of Mechanical Engineering, Nelson Mandela University, Port Elizabeth 6001, South Africa

Introduction

The continuous pursuit of enhanced propulsion systems has led to a growing interest in alternative fuels that can improve the efficiency, environmental sustainability, and overall performance of jet engines. Traditional aviation fuels, such as Jet-A and JP-8, have long been the standard in aerospace propulsion due to their high energy density and stability. However, concerns over fossil fuel dependence, emissions, and the evolving needs of advanced propulsion systems have spurred experimental research into novel fuels. These include biofuels, synthetic fuels, hydrogen-based alternatives, and fuel blends with advanced additives. This paper presents an experimental study aimed at evaluating the propulsion efficiency of jet engines using various novel fuels under controlled laboratory and semi-realistic conditions. The goal is to assess the impact of fuel composition on combustion efficiency, thrust generation, specific fuel consumption, and emission characteristics [1].

Description

The experimental investigation was conducted using a modified small-scale turbojet engine test bench equipped with advanced sensors and real-time data acquisition systems. Four fuel types were selected for testing: standard Jet-A (control), a second-generation biofuel derived from camelina oil, a Synthetic Paraffinic Kerosene (SPK) blend, and a hydrogen-enriched biofuel mixture. Each fuel underwent pre-combustion analysis to determine energy density, flash point, and viscosity, ensuring compatibility with engine hardware. Combustion chamber modifications, including fuel nozzle adaptors and reinforced seals, were implemented to accommodate the varying properties of the alternative fuels. The engine was run through a series of operating points simulating different flight regimes, from idle to maximum thrust, with data recorded for each scenario.

Results showed that the hydrogen-enriched biofuel produced the highest combustion efficiency, demonstrating a 7–10% improvement in Thrust-Specific Fuel Consumption (TSFC) compared to Jet-A. This improvement is attributed to hydrogen's high flame speed and clean combustion characteristics, which facilitated more complete fuel oxidation. The SPK blend also performed competitively, with slightly better efficiency than Jet-A and significantly lower particulate emissions. The camelina-derived biofuel, while sustainable and biodegradable, exhibited a moderate drop in efficiency due to its lower energy density. However, its performance was still within acceptable operational limits and met emissions regulations, showcasing its viability as a low-carbon alternative.

Thermal and emissions analysis revealed distinct combustion patterns for each fuel. The hydrogen-enriched blend displayed the lowest CO and unburned hydrocarbon emissions, with near-zero soot formation. The SPK blend also exhibited a cleaner burn, while camelina biofuel showed higher CO_2 output due to incomplete combustion at lower temperatures. Infrared thermography of the exhaust plume confirmed the correlation between flame temperature and emission profiles, supporting the hypothesis that fuel chemistry significantly influences propulsion thermodynamics. Additionally, engine wear and deposits were examined post-experiment, with alternative fuels showing reduced carbon buildup compared to conventional Jet-A.

A key component of the study was the comparative analysis of fuel-to-thrust efficiency. This metric, defined as the ratio of chemical energy input to mechanical thrust output, demonstrated that hydrogen enrichment offers a promising route to high-performance, low-emission propulsion. The SPK fuel's synthetic formulation allowed precise control over molecular composition, resulting in consistent and efficient combustion. Conversely, the biofuel's variability, rooted in feedstock and production methods, suggests a need for further refinement and standardization before widespread adoption. Nonetheless, the experimental data affirmed the feasibility of integrating these fuels into existing propulsion systems with minimal retrofitting [2].

Conclusion

This experimental study highlights the significant potential of novel fuels in advancing jet propulsion efficiency and environmental sustainability. Among the tested fuels, hydrogen-enriched biofuels and SPK blends showed superior performance, offering both operational and ecological advantages over traditional Jet-A fuel. While biofuels like camelina oil-derived kerosene demonstrated lower efficiency, they still represent an important step toward greener aviation. Continued research, including engine optimization and hybrid fuel systems, will be essential for maximizing the benefits of alternative fuels. As aerospace industries face increasing pressure to reduce carbon emissions and improve fuel economy, novel fuels will play a central role in the next generation of propulsion technologies.

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Conflict of Interest

None.

***Address for correspondence:** Noura Haddad, Department of Mechanical Engineering, Nelson Mandela University, Port Elizabeth 6001, South Africa, E-mail: noura@haddad.sa*

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