Single-stage jet engine research for the reduction of vapor contrails, emissions, noise, and vibrations in order to decrease the greenhouse effect

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Background

- Although traditional fossil fuel-based aviation fuels are commonly known to produce large amounts of harmful emissions, they are still the primary fuel used today.
- Synthetic fuels Isoparaffinic Kerosene (IPK) and Syntroleum 8 (S8), often derived from the Fischer-Tropsch process, are a synthetic alternative fuels which produce less greenhouse gasses upon combustion.
- Common emissions emitted from the Turbine combustion process include carbon dioxide (CO2), Nitrogen Oxides (Nox), Water Vapor (H2O), and unburnt hydrocarbons (UHC) [6].
- A single-stage turbo jet engine integrated within an experimental test cabinet (which includes thermocouples and pressure sensors across the critical stages of the combustion process) will be used to gather the synthetic fuel combustion characteristics
- The sound, vibrations, and emissions data will be collected through the application of high precision measurement microphones, accelerometers, and the MKS emissions analysis system.

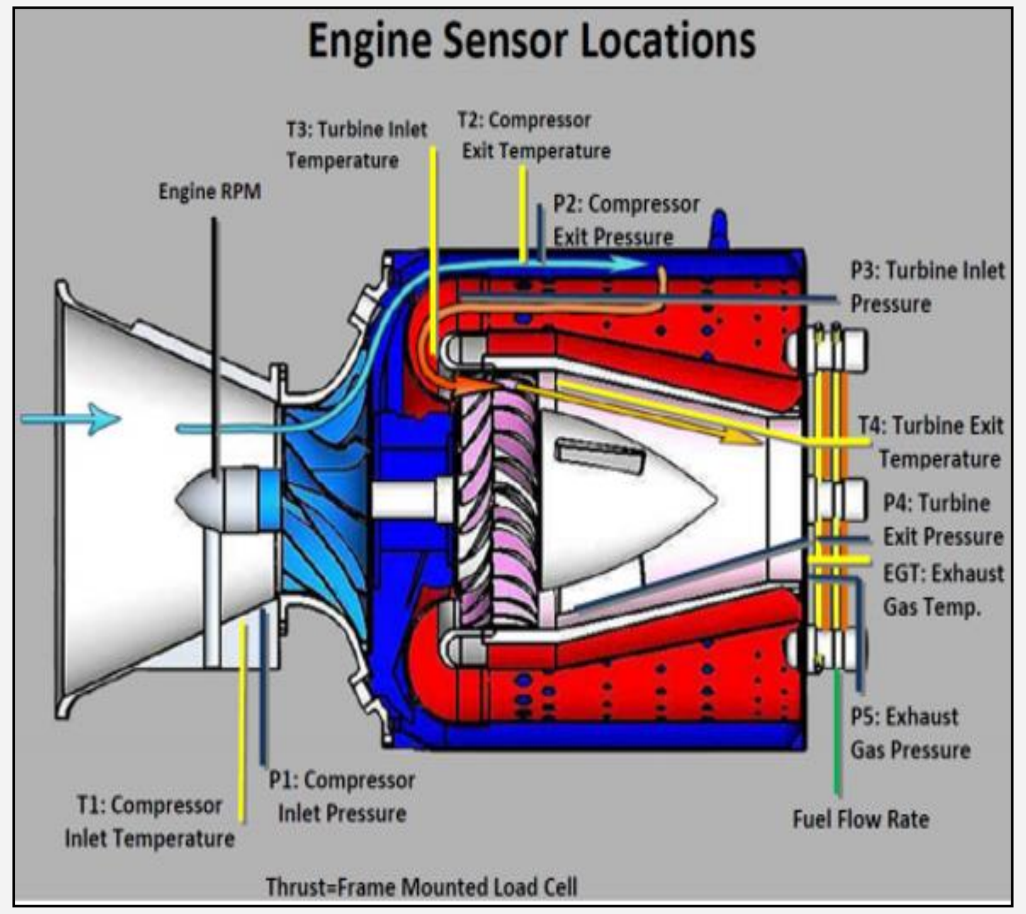
Objective

Within the aviation industry, the excessive amounts of greenhouse gasses such as carbon dioxide, water vapor, and other harmful emissions can be drastically reduced through the application of combustion analysis of synthetic fuels and the mitigation of combustion instabilities.

Literature Review

- Within the next twenty years, it is predicted that the global aviation industry will grow by 3% per year [1].
- According to the Intergovernmental Panel on Climate Change, the aviation industry contributes to approximately 2.0% of the global carbon dioxide emissions [2].
- One of the most prevalent jet engine emissions produced from the combustion process is water vapor, and water vapor directly correlates to the formation of Contrails. At the high cruising altitudes of airliner operations, contrails can become trapped and last for extended periods of time. While suspended in the upper atmosphere, the contrails trap heat which further contributes to the overall greenhouse effect [3].
- The sounds emitted by the Aerogas turbine engine occur across a wide frequency spectrum (Approximately 0. 0 – 25.6 kHz) which can be analyzed using math modifiers such as the Fast Fourier Transform (FFT) and the Constant Percentage Bandwidth (CPB). The total sound energy produced by the engine is composed of multiple thermodynamic sources, including the air intake, combustion, and exhaust [4].
- When using Synthetic lean fuels as an alternative, the stability of each new fuel must be researched because combustion instability creates supplementary gaseous emissions, noise, and vibrations within the jet engine's components [5].

Figure 1: Single Stage Turbo-Jet Engine



Acceleration

Figure 2: Overall Jet-A Acceleration

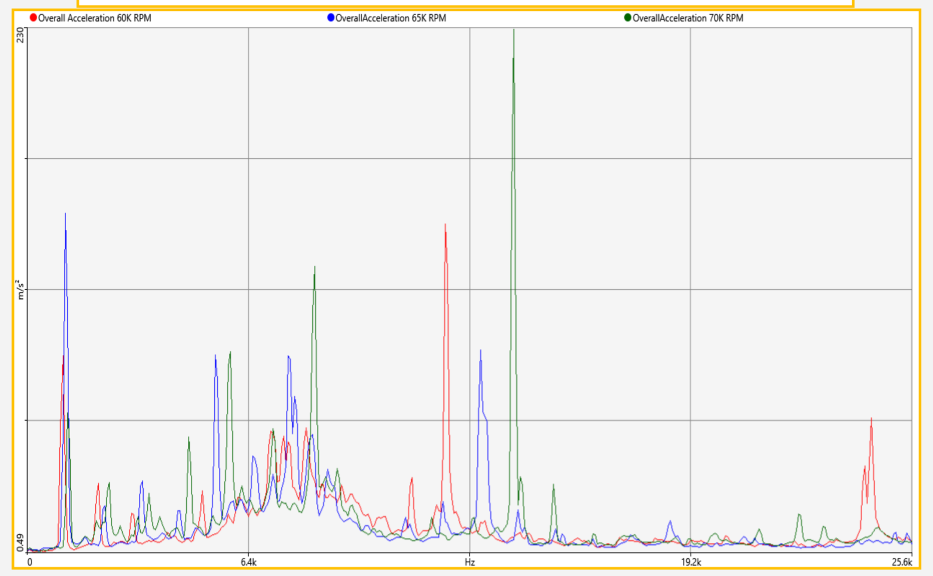
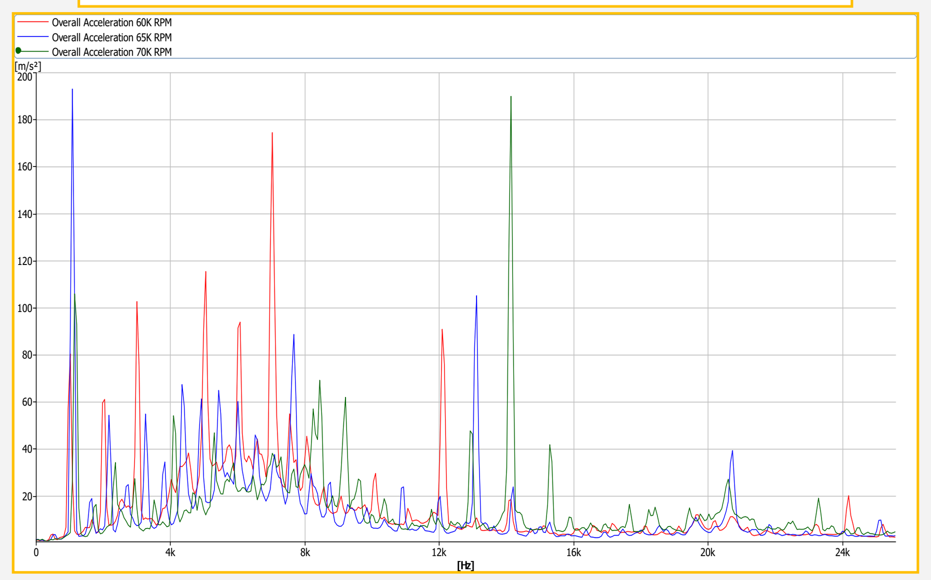
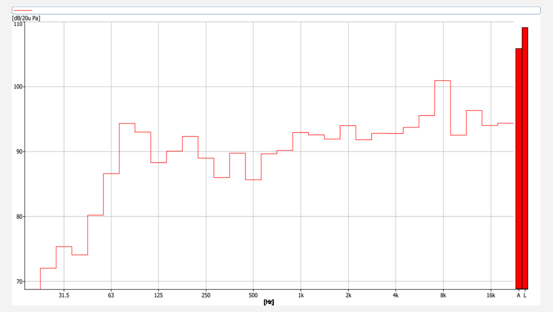


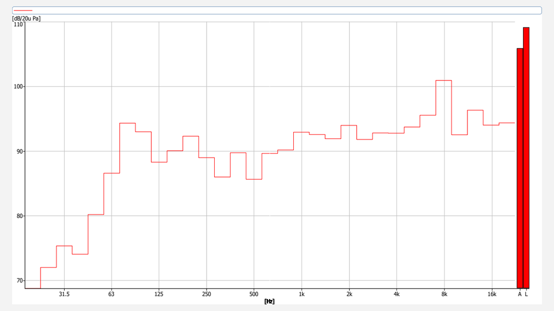
Figure 3: Overall IPK Acceleration

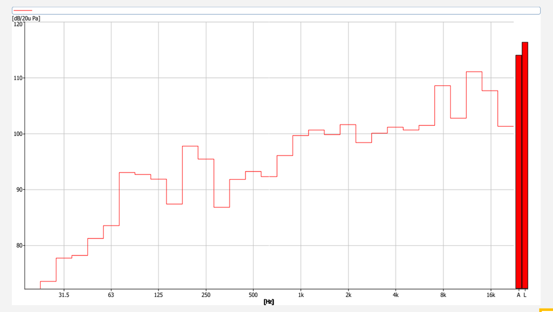


Sound Pressure

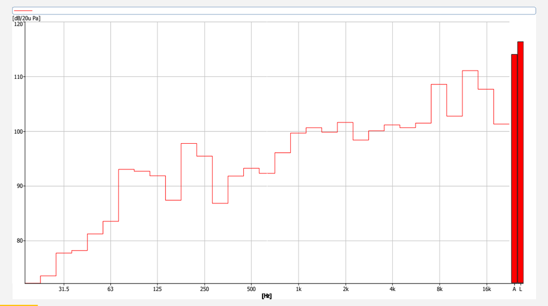


Overall Multifield Sound Pressure IPK (Left) Jet-A (Right)





Overall Freefield Sound Pressure IPK (Left) Jet-A (Right)



Emissions

Figure 4: Jet A Emissions Data

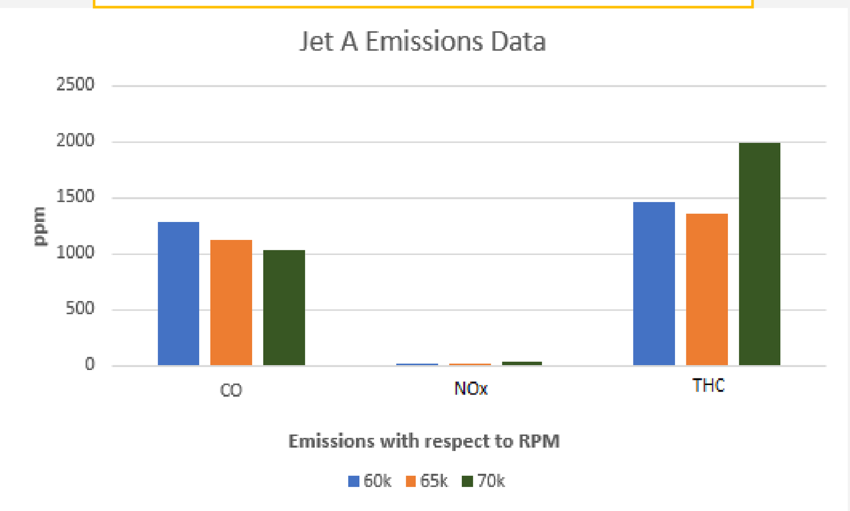
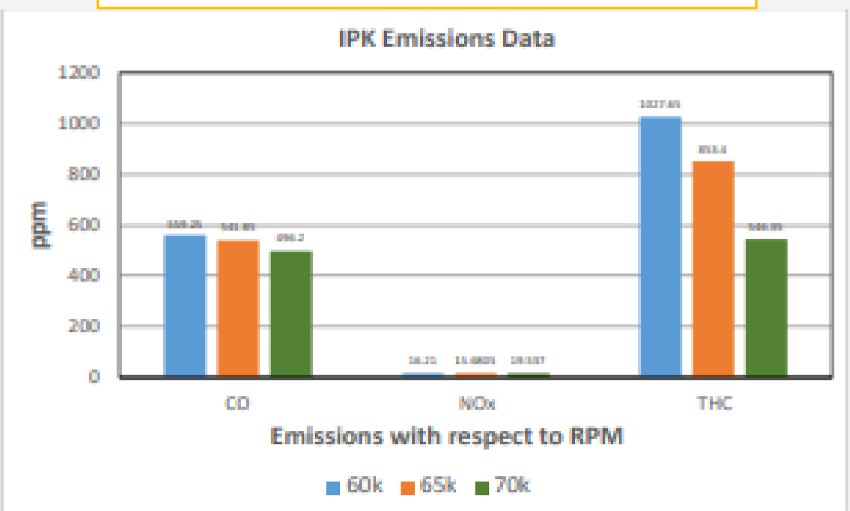


Figure 5: IPK Emissions Data



Results/Conclusions

- The overall acceleration (Acceleration values from 60,000, 65,000, and 70,000 RPM) for both Jet-A and IPK (Figures 2 and 3) follow a similar trend, with IPK showing a greater magnitude of acceleration in the upper frequency range of operation (Approximately 16 kHz – 25.6 kHz).
- Analyzing the overall Acceleration waveforms, it can be determined that the operating frequency of the Turbine with IPK fuel is approximately 1.08 kHz at 60K RPM and for Jet-A 1.15 kHz.
- Both the multifield and freefield transducers show a general increase in sound as RPM increases. The freefield microphone displays a greater peak sound pressure in comparison to the multifield microphone. This phenomena is caused by the freefield microphone being located nearer to the exhaust outlet than the multifield microphone.
- As RPM increased during testing, the overall emissions performance of the turbine increased as well. It was also found that RPM values higher than 65k led to an increase in emission of NO_x (Figures 4 and 5).

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