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FLAME EMISSION SPECTROSCOPY IN A PARAFFIN-BASED HYBRID ROCKET

Abstract

A spectrometer was used to measure the emissions emanating from the plume and combustion chamber of a paraffin-based hybrid rocket. Flame emissions were captured between 200-900 nm at numerous points during the 3-7 second ground tests. Time-resolved blackbody emissions were obtained, as well as emission and absorption peaks associated with combustion products, emanating from the plume and combustion chamber. Plume measurements were taken seven inches aft of the nozzle exit plane at the center of the plume.

The rocket is described in Narsai et al.[1] and utilizes paraffin and additives as fuel along with gaseous oxygen as the oxidizer. Chamber pressure and oxidizer flow rates were varied in order to validate results over a wide range of operating conditions. The blackbody emissions were fit to Planck's law in order to estimate flame temperature. The observed temperatures matched well with simulations run via a chemical equilibrium solver[2]. Further validation of the algorithm used to estimate flame temperature was provided by capturing emissions from a tungsten filament. Additionally, numerous species of interest were identified, including igniter materials and combustion products which contributed to erosion of the nozzle.

Two other techniques for estimating flame temperature were investigated: (1) the analysis of OH emission bands near 315 nm and (2) the analysis of the sodium D-lines around 590 nm. Trace amounts of sodium chloride were added to the melted paraffin wax prior to spin-casting in order to attempt to produce D-line emissions.

Absorption spectroscopy was conducted on paraffin and a blackener dye used to improve the absorption of thermal radiation at the exposed surface of the fuel grain. Absorption spectra were acquired between 0.2 and 22 microns. These absorption spectra were compared with flame emission spectra within the combustion chamber in order to gain insight into how heat is transferred from the flame to the fuel surface.

References

[1] Narsai, P., Momanyi, E., Venkataraman, K., Evans, B., and Cantwell, B., "Indirect Heat Flux Measurements at the Nozzle Throat of a Hybrid Rocket Motor," AIAA 2015-4132, 51st AIAA/SAE/ASEE Joint Propulsion Conference, 27-29 July 2015

[2] Gordon, S. and McBride, B.J., "Computer Program for Calculation of Complex Chemical Equilibrium Compositions with Applications," NASA Reference Publication 1311, 1996