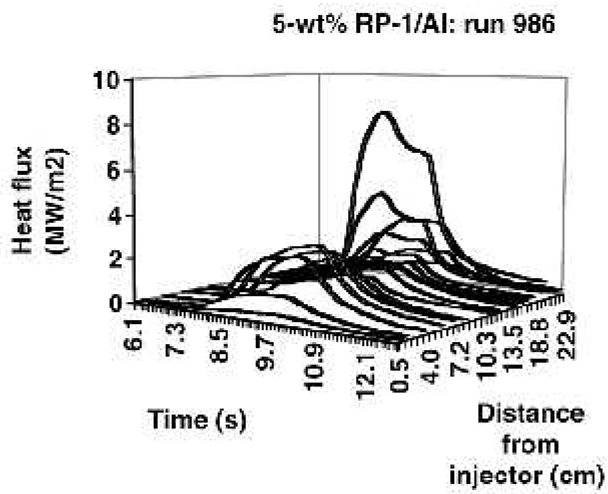
Metallized Gelled Propellants: Heat Transfer of a Rocket Engine Fueled by Oxygen/RP-1/Aluminum Was Measured by a Calorimeter

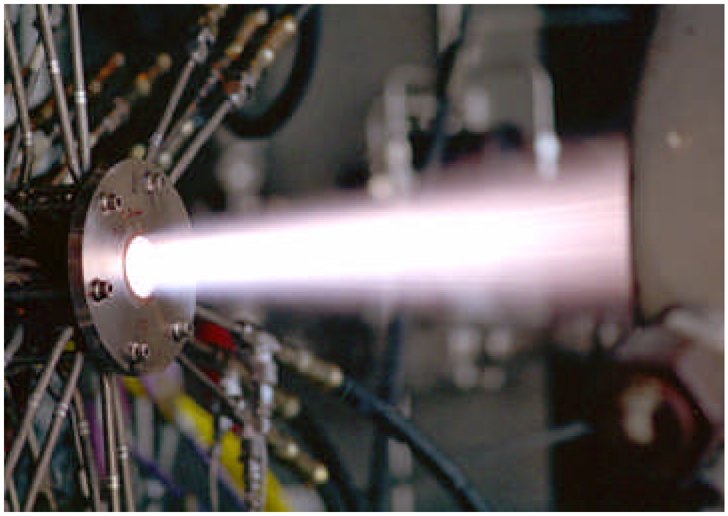
A set of analyses was conducted to determine the heat transfer characteristics of metallized gelled liquid propellants in a rocket engine. These analyses used data from experiments conducted with a small 30- to 40-lbf thrust engine composed of a modular injector, igniter, chamber, and nozzle (refs. 1 and 2). The fuels used were traditional liquid RP-1 and gelled RP-1 with 0-, 5-, and 55-wt % loadings of aluminum (Al) with gaseous oxygen as the oxidizer. Heat transfer measurements were made with a calorimeter chamber and nozzle setup that had a total of 31 cooling channels (refs. 1 and 2).

A gelled fuel coating, composed of unburned gelled fuel and partially combusted RP-1, formed in the 0-, 5- and 55-wt % engines. For the 0- and 5-wt % RP-1/Al, the coating caused a large decrease in calorimeter engine heat flux in the last half of the chamber. This heat flux reduction was analyzed by comparing engine firings and the changes in the heat flux during a firing at NASA Lewis Research Center's Rocket Laboratories. This work is part of an ongoing series of analyses of metallized gelled propellants.



Three-dimensional roller-coaster plot of metallized gelled propellant heat flux: 5-wt % RP-1/Al.

A three-dimensional roller-coaster plot for the 5-wt % RP-1/Al is provided in the preceding graph. This plot shows the engine heat flux as it varies with time and location along the axis of the engine. There are three distinct sections to the plot: the first half of the chamber (0 to 7.6 cm), the second half (7.6 to 15.2 cm), and the nozzle (15.2 cm to the end). The initial heat flux peak was created by the igniter firing; the lower steady-state value (or flat part of the curve) represents the main propellant combustion. The peak nozzle flux reached a value of 6.5 MW/m^2. In the first half of the chamber, the flux reached a peak value, but not a steady-state value; and in the second half, the heat flux quickly reached a steady-state value that was significantly lower than the peak value in the first half of the chamber. This heat flux difference was caused by the formation of a gelled layer.



5-wt % RP-1/Al rocket engine firing.

The gelled layer formed in several steps. As the gelled fuel was injected into the chamber, the O_2 gas streams impinging on the gelled fuel stream caused a ligand structure to form (ref. 3). Some of the propellant, rather than undergoing combustion, deposited on the chamber walls. An intense combustion environment was present in the chamber, but the gelled fuel was not completely atomized and, therefore, not consumed. Additional shear stress, which could be delivered by improved injector designs, would be needed to completely atomize the propellants. After the gel deposited on the walls, some of this propellant vaporized and contributed further to the combustion process, but some of it remained on the walls.

Gelled propellant layer formed in the chamber after many firings.

References

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