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Title

Mass Transfer due to Liquid Layer Flow for Paraffin-Based Fuels in Hybrid Rocket Engines

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Abstract

Paraffin-based hybrid rocket fuels have low melting points and fast-burning rates, and they are excellent candidates as propellants for hybrid propulsion. A thin liquid layer with low melt-layer viscosity and surface tension is produced on the surface of solid fuel, and entrainment of liquid droplets occurs on the unstable liquid layer surface under the shear force associated with oxidizer flow. This entrainment mechanism increases the mass transfer rate of the solid fuel in addition to the vaporization regression rate [1]. This research introduces and investigates a new mass transfer mechanism for liquefying fuels. A large quantity of liquid layer on the solid fuel surface flows out of a motor without mass transfer of the droplet entrainment or vaporization, and it was confirmed that the regression rate due to the liquid layer flow was a nonnegligible mass transfer mechanism. A two-dimensional slab hybrid motor was manufactured to investigate the regression rate due to the liquid layer. And three types of paraffin-based fuel having different liquid melt layer viscosity are used in this research, which are PR100 (pure paraffin), PR95PE05 (95 wt% pure paraffin and 5 wt% low-density polyethylene), and PR90PE10 (90 wt% pure paraffin and 10 wt% low-density polyethylene). These fuels had a thin liquid layer on the solid fuel surface during the combustion, and mechanical entrainments of liquid droplets from the liquid layer were also observed in the firing tests. The total regression rate and the regression rate due to the liquid layer flow were measured separately using the slab motor, and it was confirmed that the ratio of the regression rate due to the liquid layer to the total regression rate was considerably large. It can be concluded that the total regression rate for the paraffin-based fuels is a sum of the vaporization regression rate, the entrainment regression rate, and the liquid layer regression rate. And the effect of the liquid layer viscosity on the regression rate was also investigated using the three types of fuels. The viscosity has an important effect on the mass transfer rate due to the liquid layer whereas the viscosity did not have any noticeable effect on the rate of liquid droplet entrainment. It is quite important to understand the mass transfer mechanism for predicting rocket performance and for designing hybrid motors using paraffin-based fuels, and we will discuss it in this paper.

References

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