Paper ID: 100495
student

IAF SPACE PROPULSION SYMPOSIUM (C4)
Solid and Hybrid Propulsion (2) (4)

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PERFORMANCE IMPROVEMENT BY VORTEX COMBUSTION FOR A MAGNESIUM-LOADED HTPB/N2O HYBRID ROCKET FOR SMALL SPACECRAFT

Abstract

Miniaturization, safety, and high thrust are essential for small spacecraft propulsion systems. As a candidate for these propulsion systems, we focus on a hybrid thruster using solid fuel and a liquid oxidizer. Since miniaturization is a key requirement for small spacecraft propulsion systems, this study aims to enhance the energy density of the fuel by adding magnesium. Additionally, our group is researching a Microwave Discharge Ignition system, where magnesium induces an electric field concentration effect.

We previously developed a 1 N-class hybrid thruster using HTPB embedded with magnesium powder (10-50wt%) as the fuel and nitrous oxide (N2O) as the oxidizer. The grain is single-port type, and a post-chamber was introduced to achieve a characteristic chamber length (L^*) of 1.9 m. Combustion tests showed that when using pure HTPB (without magnesium addition), the characteristic velocity (C^*) efficiency reached a maximum of only 74%, which is lower than that of typical hybrid rocket systems.

To investigate the impact of L^* on thruster performance in more detail, we changed the post-combustion chamber volume. Compared to L^*=0.1 m, at L^*=1.9 m, C^* efficiency improved by 57%, and the fuel regression rate increased by 142%. Therefore, it is necessary to ensure sufficient L^* even in small propulsion systems. However, adding a post-chamber to increase L^* in small propulsion systems with high structural mass ratios leads to particularly significant heat losses, and thus does not necessarily improve performance.

Consequently, we are currently developing designs that can reduce heat losses even with large L^* values. The design has two main features: first, an oxidizer swirl flow to lengthen the gas path to the nozzle, and second, end-face fuel combustion to surround the combustion chamber with fuel, reducing contact with the casing and minimizing heat loss. We also analyzed how adding magnesium affects combustion efficiency and the fuel regression rate. The results will also be presented in this study.