SPACE PROPULSION SYMPOSIUM (C4)
Propulsion System (2) (2)

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VERIFICATION OF THE THROTTLING CHARACTERISTICS OF AXIAL-INJECTION END-BURNING TYPE HYBRID ROCKETS

Abstract

The axial-injection end-burning type hybrid rocket originally proposed twenty years ago by Nagata and Hashimoto et al. recently recaptured the attention of researchers for its virtues such as constant ξ (oxidizer to fuel mass ratio) during firing and throttling operations. Previous studies revealed that, for combustion in a single-port fuel grain, the end-face regression rate in the axial direction is proportional to pressure, with a pressure exponent of 0.95. Accordingly, these rockets were expected to display good throttling characteristics. Given that no ξ shift occurs, keeping the oxidizer mass flow rate within 1% of its initial design point ensures specific impulse will remain within 97% of its design point. There are several requirements for realizing this type of hybrid rocket: 1) high fuel filling rate for obtaining an optimal ξ; 2) small port intervals for increasing port merging rate; 3) ports arrayed across the entire fuel section. Because common manufacturing methods were unable to produce a fuel that satisfied these requirements, no previous researchers have conducted experiments with this kind of hybrid rocket. Recent advances in high-accuracy 3D printing have enabled such fuels to be produced for the first time. The fuel grains used in this study were produced by a high-precision light polymerized 3D printer. Each grain consisted of an array of 0.3 mm diameter ports for a fuel filling rate of 98%. Last year, the authors reported the results of multiple firing tests of an axial-injection end-burning type hybrid rocket using 3D printed fuel grains and verified that solid fuel regression rate is linearly dependent on pressure. In this study, the authors conducted a unique set of experiments to verify the throttling characteristics of the axial-injection end-burning type hybrid rocket. Oxidizer mass flow rate and chamber pressure were throttled during firings by actuating valves in a fluid circuit consisting of four oxidizer supply lines. Chamber pressure and oxidizer mass flow rate were measured during each firing. These experimental data were analyzed by a reconstruction technique to obtain ξ history. The results show that ξ remains almost constant during firing, even during throttling operations. Therefore, this study verifies that the axial-injection end-burning type hybrid rocket has superb throttling characteristics. Additionally, the study supports findings in previous research that indicate the pressure exponent is close to unity.