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COMBUSTION PERFORMANCE OF A STAGED HYBRID ROCKET WITH BORON ADDITION

Abstract

Staged hybrid rocket engine (HRE) is a newly introduced concept of HRE by the recent study. It can minimize the loss of combustion performance with the oxidizer-to-fuel (O/F) shifting, while maintaining the key advantages of HRE. It uses the hybrid gas generator (GG) as a primary combustor, which utilizes solid fuel and gas/liquid oxidizer to produce fuel-rich effluent, which is then expelled and mixed with additional aft-injected secondary oxidizer in the secondary combustor for thrust generation.

The use of oxygen and nitrogen mixture oxidizer is one of techniques to generate fuel-rich effluent that meets the design requirement of GG. Equivalence ratio had increased significantly with decreasing oxygen (O2) content (by volume) in the mixture oxidizer, resulting in substantial decrease in the effluent temperature. In the results, with the use of hydroxyl-terminated polybutadiene (HTPB) and 28% oxygen content mixture oxidizer, the fuel-rich effluent with a temperature of 1290 K was successfully produced, which was in the range of the design requirement of GG. However, a loss of Isp (specific impulse) was inevitable due to deliberately decreased oxygen content in mixture oxidizer. Though the staged HRE offers many advantages, its Isp should be improved to be at least competitive with conventional chemical rockets to outweigh its advantages.

Meanwhile, an addition of metal additives to solid fuel is widely used technique to improve the Isp as well as fuel density. Hence, with use of metal additives in staged HRE, this could bring an enhancement of Isp and therefore possibly be competitive with other chemical rockets with respect to Isp performance. However, loading limit of metal additives in solid fuel should be carefully chosen for a possible combustion instability. As this study is likely to be the first attempt to study the effect of metal additives in staged HRE, this study has limited metal additives content up to 10 wt%. As for the metal additive candidate, boron was selected as it is reported to have the highest combustion enthalpy per mass and volume.

The key purpose of boron addition is to compensate the Isp loss; therefore, the main objective of this study is to determine if an improvement in Isp is possible with the addition of boron. The results proved that a boron addition provided a significant improvement in Isp, by about 13 % when compared to the pure HTPB. Future study will focus on experimental tests to valid the findings.