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

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NUMERICAL SIMULATION BASED OPTIMIZATION OF SEGMENTED GRAIN FOR HYBRID ROCKET MOTOR

Abstract

Hybrid rocket motors (HRMs) offer many attractive advantages in terms of easy thrust control and safety. However, HRMs have lower fuel regression rate and combustion efficiency, and more variable mixture ratio compared to solid rocket motors. As an important design concept to improve the specific impulse, segmented grain is able to achieve the target of multilevel thrust and high combustion efficiency. This study focuses on the optimization of segmented grain of variable thrust HRM for a sounding rocket, with the objective of obtaining high average specific impulse. This problem refers to two aspects. On the one hand, the grain types of each segment should be optimized to improve the combustion efficiency. On the other hand, the geometry of each segment of the grain should be optimized to decrease the extent of the mixture ratio transformation to decrease the energy loss caused by off-peak operation. A variable thrust HRM with two levels is studied here. The optimization objective is the average specific impulse of the operation, and the variables are the grain type of each segment and the corresponding geometry parameters. The increasing popularity of high fidelity computational fluid dynamics simulations in combustion flow has stimulated the research into more efficient design optimization methods. The design parameters of the grains were optimized using differential evolution (DE) algorithm combined with response surface method (RSM) approximation in this effort. Performances of design candidates were evaluated by the specific impulse based on the 3D geometry design and the full combustion flow analysis using commercially CAD and CFD packages. In order to reduce the computational cost, the RSM interpolation was employed to approximate the objective function in the adaptive surrogate based design optimization process. The reasonable solution had been finally achieved with low computational cost, which increased the average specific impulse remarkably compared to the original design.