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IMPROVEMENT ON THRUST PROFILE FLEXIBILITY BY OXIDIZER-TO-FUEL RATIO FEEDBACK CONTROL IN HYBRID ROCKET

Abstract

The versatility in rocket operations is a key feature for the economic space transportation. In hybrid rocket, however, wide range throttling from nominal thrust profile causes residue of propellant and it affects the effective structural efficiency. This is because the oxidizer-to-fuel ratio, O/F, changes passively depending on the thrust history. Here we study improvement of thrust profile flexibility by implementing an O/F feedback control system in Altering-Swirling-Oxidizer-Flow-Type hybrid rocket. This type of rocket manipulates its fuel regression rate by swirling intensity in the chamber. Therefore, it can control the oxidizer flow rate and the fuel regression rate independently. To analyze the flight performance of the hybrid rocket, a mathematical rocket model including the O/F feed back system is constructed. In the model, thrust profiles and structural geometrical parameters are treated as design variables, and multi-objective optimization techniques are used to obtain a solution set that satisfies multiple mission requirements. The improvement in thrust profile flexibility is discussed by comparing the solution sets with/without the O/F control system.

In this study, we treat design problems in a single-stage generic hybrid rocket. Here a generic rocket means a single rocket operated in several flight profiles by using its throttling ability. For example, a simple ballistic flight and a horizontal flight in high altitude can be thought as the typical flight profiles. The computation of the rocket flight is based on three degree of freedom rigid body dynamics. In the hybrid rocket model, the fuel mass flow rate is computed from a regression rate formula and solid fuel grain geometry, and the chemical equilibrium state is assumed in the combustion chamber to compute the thrust. The O/F feedback control system is composed of an onboard O/F estimator and the Altering Swirling-Oxidizer-Flow-Type hybrid rocket and some simple proportional feedback rules.

The hybrid rocket model has some design parameters, including the oxidizer tank volume and the thrust profile. These parameters determine the flight trajectories. After the flight simulation is finished, generated flight trajectories are evaluated by several criteria. For example, duration time of micro-gravity environment and staying time in target altitude can be defined as the criteria. Therefore, feasible thrust profiles can be extracted as a solution set by solving multi-objective optimization problem for these criteria. In this study, Multi-objective Optimization Genetic Algorithms are used to obtain the solution set.