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EXPERIMENTAL INVESTIGATION ON THE ANTI-ABLATION PROPERTIES OF MULTI-MATERIAL INTERFACE NOZZLE INSERT IN HYBRID ROCKET MOTORS

Abstract

Hybrid rocket motors can be applied to the upper stage of launch vehicles and propulsion system of spacecraft when landing the moon and Mars due to their advantages, such as thrust controllability, low cost and environmental compatibility. However, serious nozzle erosion is a key problem that prevents hybrid rocket motors from widespread use.Beihang University has been developing a long-time working hybrid rocket engine with 3 kN class thrust, using hydroxyl-terminated polybutadiene (HTPB) as the base fuel and 98% hydrogen peroxide as the oxidizer. Three nozzles with combination structure are manufactured and tested in the firing experiment, with a contraction ratio (Ac/At) of 47.1 and expansion ratio (Ae/At) of 3.1. The working time of all three tests are 200s. The three nozzles are made of carbon/carbon infiltration pottery, carbon/carbon, high silica phenolic resin and steel (30CrMnSiA). The convergence section and nozzle throat are made of carbon/carbon infiltration pottery that is exposed to the axial impact of high-temperature gas. The carbon/carbon material is used in the expansion section. The high silica phenolic resin and steel are employed as thermal insulation layer and supporting structure. In the second and third nozzles, copper infiltrated tungsten is equipped in the convergence section and throat. In addition, a numerical model on multi-boundary interface nozzle is established and verified. A characterization in terms of different nozzle materials upon the erosion distribution has been derived for the three nozzles. Thermochemical reactions of oxidizing species with carbon and tungsten are taken into account.This paper presents the main results of the three firing tests and the simulation. The parameter analysis of nozzle erosion behavior is demonstrated. In the experiments, the average mass consumption ratios of oxidizer/fuel in the three tests are 3.94, 4.33 and 3.97. The erosion rates of the three nozzles are 0.072, 0.133 and 0.024 mm/s. The simulation results are consistent with the experimental results. It is concluded that an optimal design of the thermal protection structure and the application of the copper infiltrated tungsten could improve the nozzle performance. In addition, the larger ration of oxidizer/fuel mass consumption could be the main reason that causes the higher erosion rate for the second nozzle. Furthermore, there may be an optimal mass ratio of oxidizer/fuel for the minimum erosion rate. Finally, an outlook is given on the design of future nozzle configuration and material selection for the hybrid rocket motor.