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NUMERICAL AND EXPERIMENTAL STUDY OF GRAPHITE NOZZLE EROSION IN HYBRID ROCKET MOTOR WITH STAR GRAIN

Abstract

Hybrid rocket motor is a promising propulsion system because of its intrinsic advantages over conventional solid rocket motor and liquid rocket engine. However, serious nozzle erosion is a key problem that prevents hybrid rocket motor from widespread use, especially for the long-time working propulsion system. This paper is intended to analyze the nozzle erosion in hybrid rocket motor through both numerical and experimental methods. In this paper, the erosion of a graphite based nozzle coupled with combustion flow field is studied in a hybrid rocket motor with star grain. 90% hydrogen peroxide and hydroxide-terminated polybutadiene are adopted as oxidizer and fuel, respectively. The nozzle erosion is simulated coupled with the flow field in a typical hybrid rocket motor through three-dimensional numerical simulations. The simulations are based on a pure-gas steady numerical model considering turbulence, fuel pyrolysis, oxidizer/fuel reaction, thermal conduction and solid-gas boundary interactions on fuel and nozzle surfaces. Radicals are also taken into account in the reaction model and the solid-gas boundary interaction model. The results indicate that the nozzle erosion is greatly influenced by the inner flow field. Compared with the flame near the grain peak, the flame near the grain trough is thicker. Therefore, the maximum erosion rate (0.042mm/s) occurs in the area of nozzle throat corresponding to the grain trough. OH and H_2O contribute 49.8% and 45.5% for the erosion rate in this area. Meanwhile, 56.6% and 31.9% contributions are made by OH and H_2O in the area corresponding to the grain peak. O, CO_2 and O_2 make much lesser contributions for the total erosion. Besides, a firing test is also carried out to characterize the graphite nozzle erosion on a full scale hybrid rocket motor with star grain. The nozzle inner profiles before and after test show that the erosion behavior of graphite material is strictly related to the fuel shape. The experimental result is in good agreement with the simulation one. However, erosion rate of the firing test is more scattered than that of the numerical simulation. This is due to the asymmetric oxidizer injection and combustion.

Keywords: Hybrid Rocket Motor, Nozzle Erosion, Star Grain