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NUMERICAL SIMULATION AND EXPERIMENTAL TESTING ON SEGMENTED GRAIN HYBRID ROCKET MOTOR

Abstract

Hybrid rocket motor (HRM) provides a number of advantages such as simplicity throttling and shutdown, safety, low cost, grain robustness, and propellant versatility over a classical solid-propellant or liquid-propellant rocket. However, the HRM has suffers from lower fuel regression rate and combustion efficiency due to insufficiency mixing between core oxidizer flow and the gasified fuel off the grain surface. The issue becomes worse as the rocket scale increases. Large and volumetric post combustion chamber is commonly used to enhance mixing, while its application is limited because of restricted structure and mass. Application of segmented grain is effective way to enhance propellant mixing and enlarge the resident time of combustion gas in the combustion chamber. Segmented fuel grain consists of fore-section and after-section and the two parts adopt different fuel types respectively. The mixing is promoted when combustion gas transiting from fore-segment to after-segment, thereby the combustion efficiency is improved. The combination of tubular grain in fore-segment and multiport grain in after-segment is studied in this paper. The equivalent port diameters of the two section are equal for designing in the optimum oxidizer-to-fuel ratio. A segmented grain combined by tubular and multiport grain are compared with a single tubular grain. A numerical simulation model is established coupling the Navier-Stokes equations with turbulence, chemical reactions, solid-fuel pyrolysis, and solid-gas interfacial boundary conditions under the gas-liquid two-phase flow in 3-D meshes. The simulation results show that segmented grain significantly improved combustion efficiency. The corresponding firing experimental test is conducted for further research of segmented grain effects with 98% hydrogen peroxide (HP) oxidizer and hydroxyl terminated polybutadiene (HTPB) based fuel propellants. The infrared camera thermography system and the precision pressure sensor were used to acquire the temperature distribution of the exhaust plume and real-time pressure respectively. Averaged characteristic velocity and combustion efficiency were analyzed based on by acquired experiment data. The experimental test result verified that correctness of the numerical simulation analysis. Both experimental and computational results show that segment grain can increase combustion efficiency, which provide compact and efficient guidance for design of the segmented grain based HRMs.