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EXPERIMENTAL INVESTIGATION AND NUMERICAL SIMULATION ON THROTTLEABLE PINTLE-CENTRIFUGAL INJECTOR FOR HYBRID ROCKET MOTOR

Abstract

With increasing complexity of aerospace missions, higher thrust regulation performance requirements for rocket motors are demanded. Easier thrust regulation is one of the main advantages of hybrid rocket motors. In order to maintain high motor performance in the process of thrust regulation, hybrid rocket motor need to not only control the propellant mass flow, but also adjust propellant injection conditions (mainly pressure drop and flow field state). Therefore, with reference to the pintle injector, a throttleable pintle-centrifugal injector was designed, manufactured, tested and simulated. Under the test conditions with a wide range of propellant mass flow rate, the throttleable pintle-centrifugal injector realized effective control of injection pressure drop by adjusting the stroke of the pintle. At the propellant mass flow rate is 57.4g/s, the minimum injection pressure drop of the throttleable pintle-centrifugal injector is 0.07MPa, while at the mass flow rate is 392.7g/s, the minimum injection pressure drop is 0.29MPa, which shows the injection pressure drop adjustment ratio is 4.14. In contrast, the fixed structure injector has a pressure drop adjustment ratio of 46.81 for the same mass flow variation ratio. Additionally, in the experiment, as the pintle stroke increases the atomization cone angle increases and the position of the aerodynamic force on the liquid film is constantly advanced. When the pintle stroke reaches maximum, the flow field state approximates that of a centrifugal injector. The VOF-to-DPM model was used to carry out a numerical simulation research on the injection flow field of the throttleable pintle-centrifugal injector, including the liquid film unfolding, breaking and atomization processes. The numerical simulation results are consistent with the experimental results and show that the crushing and atomization process is progressively advanced and the sauter mean diameter (SMD) at the same axial position is gradually decreased, as the pintle stroke increases. Experimental investigation and numerical simulation have shown that the throttleable pintle-centrifugal injector can effectively control the injection pressure drop while reasonably adjust injection flow field state, over a wide range of mass flow rate.