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AN IMPROVED AL PARTICLE COMBUSTION MODEL FOR SIMULATING THE ALUMINIZED HYBRID ROCKET MOTOR COMBUSTION

Abstract

The hybrid rocket motor (HRM) stands as a promising propulsion system employing solid fuel and liquid oxidizer as propellant, capable of achieving thrust variation at a low cost. The addition of Al particles to the solid fuel has demonstrated the potential to enhance the regression rate and specific impulse for HRM. Hence, the investigation into the combustion process of aluminized HRM necessitates the development of high-precision simulation methods for Al particle combustion. However, prior numerical studies concentrating on Al combustion have oversimplified Al2O3 as a gas phase component, thereby overlooking the heat and mass transfer process during the Al2O3 phase change. Consequently, significant deviations between numerical simulation and experimental results arise, particularly with high Al content fuel. To surmount this challenge, this study proposes an improved Al particle combustion model for HRM, accounting for both the evaporation of Al particles and the generation of Al2O3 particles. A Monte-Carlo algorithm is employed to generate Al2O3 condensation nuclei within the HRM inner flow field based on Al2O3 vapor relative humidity. Moreover, the two-phase kinetic interaction between Al2O3 particles and gas-phase propellant is determined using the Euler-Lagrange method. Simultaneously, the condensation rate of the Al2O3 particles and the heat and mass transfer between the particle and the gas phase propellant are considered based on the local grid relative humidity and particle size. To validate the efficacy of this new model, a firing test is conducted on the 42%HTPB+58%Al fuel HRM utilizing 95%H2O2 as the oxidizer. Simulation is performed accordingly based on the proposed new model. The simulation results indicate that Al2O3 condensation is most pronounced within the post-combustion chamber due to vortex-induced restrictions on Al2O3 particle movement. Comparative analysis with the old model, which neglects Al2O3 particle generation, reveals that the simulation employing the new model demonstrates higher precision, reducing the deviation between simulated thrust and experimental thrust from 3.9% to 1.1% and from 7.0% to 2.4% for combustion efficiency. This study offers a valuable methodology for investigating the generation of Al2O3 particles and presents a more precise model for depicting aluminized hybrid rocket motor combustion.