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NUMERICAL SIMULATION OF COMBUSTION CHARACTERISTICS OF BORON PARTICLE IN FORCED CONVECTIVE ENVIRONMENT

Abstract

Boron-based fuel-rich propellant is of high-energy density propellant which has a widespread application prospect in the propulsion system of spacecrafts and missiles. However, most of the existent researches about the combustion characteristics of boron particle still rest on the static atmosphere, which is not coincident with the conditions in the chamber of the ramjet engine. The fields around boron particles are no longer spherical symmetric. Flame shapes of boron particles in the combustion process may vary at different Reynolds numbers. And the burning rates corresponding to the convective environment will be different of those under relatively static conditions. Unfortunately, few theoretical modeling of such cases are available at present. In the present study, the combustion characteristics of single boron particle in forced convective environment in ramjet engines are investigated systemically. A physical model is proposed taking into consideration the gas flow around the particle, the gas diffusion and the surface global single step finite reaction dynamic. A numerical simulation method is established and validated. The axi-symmetric Navier-Stokes equations along with species and energy conservation equations are solved using a finite volume technique. The density of the gas mixtures has been evaluated from ideal gas equation of state. And thermo-physical properties of the gas species have been evaluated using polynomials of the temperature. Influence factors such as the gas velocity, particle radius, the ambient oxygen mass fraction and the ambient pressure on the combustion characteristics of single boron particle are studied by numerical simulations. And the effect mechanism for each factor is analyzed in detail. The numerical prediction results show that in forced convective environment, both the mass burning rate and the mass flux of the reacting boron increase with the increase in the incoming gas flow velocity, the particle radius, the ambient oxygen mass fraction and the ambient pressure. Comprehensive analysis is conducted, and it is found that the mass flux of the reacting boron increased with the incoming gas Reynolds number. Then the mass flux of the reacting boron particle in the static atmosphere is modified to describe the combustion characteristics of the reacting boron particle at various Reynolds numbers based on abundant numerical simulation results.