MONTE CARLO SIMULATION OF RAREFIED TWO-PHASE PLUME FLOWS AT HIGH ALTITUEDS

Jie Li, Yu-Zhong Shi, Li Yan, Wei Huang
College of Aerospace Science and Engineering, National University of Defense Technology, Changsha ,Hunan,410073, China

Rarefied gas-particle two-phase plume in which the phase of particle is liquid or solid flows from the propellant rocket of reaction control systems demanding for the maneuver and brake of hypersonic vehicles flying in the high altitude,the particulates not only impact the rarefied gas flow properties,but also make a great difference to plume radiation signature,so the prediction of the rarefied gas-particle two-phase plume flow characteristics is very important for space target recognition and penetration of hypersonic vehicles. In the microthrusters, which is used for the spacecraft such as the satellite for the attitude control, rarefied two-phase plume flow also exists, which attacts an increasing attention due to the surface contamination and heating control.The present investigation has focused on the two-phase flow in which the gas phase is continuous, and the study on the gas-particle two-phase flow in which the gas phase is noncontinuous is developing as well. Accordingly, this project aims to study the rarefied gas-particle two-phase plume flow. Based on the microcosmic physical parameters describing the movement of particles, the mechanical and thermal models of gas-particle interaction are constructed, the transportation mechanism of the momentum and the energy for gas-particle two-phase flow is also constructed, which is two-way coupling. The direct simulation Monte Carlo (DSMC) method is developed for the gas-particle two-phase flow in the region of rarefied gas. Simulations are performed for the verified case, the results show that the model agrees closely with the momentum and energy transfer mechanism. A Monte Carlo model is also presented for the particles with particle collision,consolidation and seperation,phase change which will influence the particle velocity and temperature, as well as the surrouding gas. A program for the two-dimensional flow and the axial symmetric flow of the gas-particle two-phase flow in the region of rarefied gas is formed. Simulations are performed for the case of gas-solid inverse jet from flat-nosed cylinder interacting with rarefied hypersonic external flows, the case of gas-solid transverse jet from a two-dimensional flat plate in the transitional regime and the case of rarefied multiphase plume flows into the vacuum. The structure of flow field and the aerodynamics properties on the surface are analyzed in details. The results show that the interacting flow fields are different on the varied Knudsen parameter and loading ratio etc. A new approach may be proposed to describe the rarefied gas-particle two-phase plume flow in this project, and the basic flowfield data for spacecraft contamination and satellite heating control are provided.