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CHEMICAL NON-EQUILIBRIUM EFFECT ON TRIM ANGLE OF MARS SCIENCE LABORATORY ENTERING MARTIAN ATMOSPHERE

Abstract

Aimed to study the chemical non-equilibrium effect on aerodynamic characteristics in the hypersonic entry process of Mars science laboratory entering Martian atmosphere, the three-dimensional Navier-Stokes equations considering chemical reaction kinetics are solved by a parallel code, in which AUSM+-up scheme were employed to discrete the convective flux and second order central difference scheme to viscous flux, LU-SGS were implemented in time marching. Since Martian atmosphere is made up of 95.7% CO2, 2.7% N2 and 1.6% Ar, 9 species containing CO2, CO, O2, O, C, N2, NO N and Ar and 10 chemical reactions were applied in chemical reaction model where only dissociation reactions and neutral exchange reactions were considered. The flow field structures around the capsule were compared with and without the chemical reaction model. The trim angle and the difference value between perfect gas model and chemical reaction gas model were obtained under typical atmospheric conditions in Mars entry by solving pitching moment under several different angles of attack. Furthermore, these values were also solved in different altitude when Mach number kept the same and in different Mach numbers when altitude kept the same to analyze the influence of altitude and Mach number on the chemical non-equilibrium effect according to the difference value of trim angle. The results show that large number of CO2 is dissociated behind the strong shock in front of the base which consume much energies; with the chemical non-equilibrium effect, the shock layer is strongly compressed; comparisons between chemical reaction and perfect gas models show that the vortex in wake flow was reduced; impacted by chemical non-equilibrium effect, the pitching moment become larger than that obtained with perfect gas model, the trim angle are separately -16.1 degrees and -18 degrees for perfect gas and chemical reaction gas, the difference value is 1.9 degrees; when Mach number kept the same, the altitude goes bigger the difference value of trim angle between perfect gas and chemical reaction gas changed a little, which shows that the influence of altitude on the chemical non-equilibrium effect to trim angle is limited; when altitude kept the same, the Mach number goes bigger the difference values of trim angle become bigger too, which shows that the influence of Mach number on the chemical non-equilibrium effect to trim angle is positive and important.