Influence of boundary slip effect on thermal environment in thermo-chemical non-equilibrium flow

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A kind of new hypersonic vehicle makes long-time flight in transitional flow regime where boundary slip effect caused by low gas density will have an important influence on the thermal environment around the vehicles. Numerical studies on the boundary slip effect as hypersonic vehicles fly in high Mach number has been carried out. The method for solving non-equilibrium flows considering slip boundary, surface catalysis and chemical reactions has been built up, and been validated by comparing the thermal environment results with STS-2 flight test data. The mechanism and rules of impact on surface heat flux by different boundary slip level (Knudsen number from 0.01 to 0.5) has been investigated in typical hypersonic flow conditions. The results show that the influence mechanisms of boundary slip effect are different on component diffusion heat flux and convective heat flux; slip boundary increases the near wall temperature which diminish the convective heat; whereas enhances the near wall gas diffusion heat because of the internal energy's growing. Component diffusion heat flux takes a smaller portion of the total heat flux, so the slip boundary reduces the total wall heat flux. As Knudsen number goes up, the degree of rarefaction increases, the influences of slip boundary on convective and component diffusion heat flux are both enhanced, total heat flux grows by a small margin, and boundary slip effect is more distinct.

Keywords: Non-equilibrium, thermal environment, boundary slip, surface catalysis