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Modeling of the Heat Transfer and Flow Characteristics of a Low-Power Hydrogen Arc-Heated Thruster

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Arc-heated thrusters (arcjets) offer significant savings in satellite propulsion system mass for a variety of missions ranging from north-south station-keeping to orbit maneuvering or orbit transfer. For many mission scenarios, this reduction in on-orbit mass enables launches with smaller vehicles than required by other propulsion systems. In most of experimental studies, hydrogen with small molecular mass, high specific heat and high thermal conductivity is often used as the arcjet propellant due to its attractive feature that high specific impulse can be obtained. Modeling study is thus conducted to reveal the heat transfer and plasma flow characteristics of the arcjet thruster with hydrogen as the propellant. The all-speed SIMPLE algorithm is employed to solve the governing equations, which take into account the effects of compressibility, the Lorentz force and Joule heating, as well as the temperature- and pressure-dependent gas properties. Quasi-LTE model with enhanced electric conductivity at the near-anode region [1] and the geometrical sizes of 1 kW class radiatively-cooled arcjet thruster designed by NASA Lewis Research Center [2] are used in this modeling.

Comparsion of the simulated and measured variations in axial velocity across the exit plane is made for the case with the arcjet operating at the arc current of 10 A and the mass flow rates of 13.3 mg/s. It is seen that the agreement is good in the central region of the plasma jet, while appreciable discrepancies appear in the fringe region due to the existence of rarefied gas effect at the anode-nozzle wall. Modeling results also show that the predicted axial variation of centerline velocity agrees reasonably with the experimental data. The energy conversion process in the arcjet thruster is also analyzed based on the modeling results.

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