Numerical Simulation of an Hall Thruster Using Three-dimensional Hybrid Schemes

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Abstract

Hall thrusters (HTs) are recognized as a pivotal technology in electric propulsion for space missions, owing to their remarkable efficiency and versatility. Offering high specific impulse values ranging from 1000 to 3000 seconds, these devices significantly outperform traditional chemical propulsion engines. HTs can operate across a wide range of power inputs, from 10 W to 100 kW, and can use noble gases such as xenon and krypton as propellants, making them fitting for a variety of space missions. These thrusters can generate thrust levels from a few millinewtons (mN) to between 1 and 5 newtons (N), making them suitable for both small and large-scale missions that require quick deep-space travel. The working principle of HTs revolves around creating a powerful electric field within the plasma chamber. To achieve this, a transverse magnetic field is introduced to reduce electron conductivity. However, the longitudinally applied electric field introduces a perpendicular drift (E×B drift) in the azimuthal motion of the electrons (1). The magnetic field is designed to strongly magnetize electrons, effectively trapping them along the magnetic field lines, while ions remain mostly unmagnetized. This configuration ensures electrons are collisional and confined by the magnetic field, whereas ions remain largely collisionless. For this cross-field discharge it is essential to have a continuous supply of electrons. This requirement is met by positioning an external hollow cathode device adjacent to the Hall discharge chamber. Typically, a hollow cathode comprises a durable tube made of refractory material, along with an insert designed to emit electrons efficiently due to its low work function. It also includes a heating mechanism, a plate positioned downstream, and an anode keeper to facilitate operation. The heating process, often initiated by coiling heaters around the cathode, raises the temperature, which in turn starts the discharge process. Subsequently, the electric field plays a crucial role in propelling the released electrons toward the anode, which operates at a high voltage (2).

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