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Numerical study on the Influences of Magnetic Field on the Discharge Characteristics in Hall Thruster Channel

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The magnetic field in Hall thruster channel is an essential factor which can restrain the electron axial conduction, change the conductivity distribution, and affect the thruster performance. In this work, the effects of different magnetic field intensities and configurations on particle number density, potential, electron temperature and ion velocity distribution are investigated by particle-in-cell simulation, and the corresponding discharge current and specific impulse are also numerically simulated. The results show that the restraint of electron axial conduction by magnetic field is weakened when the maximum axial magnetic field intensity is less than 200 Gauss; when the maximal magnetic field intensity is between 200-420 Gauss, with the increasing of the magnetic field intensity, the electron temperature, ionization rate and electron-wall collision frequency decrease, and the ion radial velocity increases. When the maximal magnetic field intensity is 280 Gauss, the acceleration region is the shortest and the discharge current become minimal. When the magnetic field configuration is changed, the magnetic field lines perpendicular to the wall near the anode which causes the ionization region to move to the anode region, and the discharge current is too small to form ionization. The zero-point position of magnetic field can change the axial lengths of ionization and acceleration regions, affect the plasma discharge characteristics.

In this work, two-dimensional physics model of Hall thruster is established to numerically simulate the effects of magnetic field intensity and configuration on plasma discharge characteristics (Fig. 1). The simulation results demonstrate that, as the magnetic field configuration remains constant and the magnetic intensity factor $k < 0.7$, when the maximal magnetic field intensity of the central axis is less than 200 Gauss, the ionization region is near the anode and the acceleration region grows. In the condition that the magnetic intensity factor $k > 0.7$ with the increase of the magnetic field intensity, the electron temperature, ionization rate and electron-wall collision frequency decreases gradually, the ion radial velocity increases, the radial potential drops and the radial velocity increases at the discharge channel exit (Fig. 2), and the thrust value stays the same. As the magnetic intensity factor $k=1$ while its maximal magnetic field intensity of the central axis is 280 Gauss, the acceleration region is the shortest and the discharge current is minimal. When the magnetic intensity factor $k > 1.3$, ion radial velocity and wall corrosion increase, but discharge efficiency reduces. While the location of the zero-point of magnetic field region moves towards to the discharge channel exit, the magnetic field configuration perpendicular to the wall restrain electrons, the acceleration region increase, the discharge current decreases sharply, and the thruster cannot sustain steady operation. When zero-point of magnetic field region nears to the inner wall of the channel, the discharge current increases obviously, the distribution of radial electric potential becomes uneven at the exit of the channel, ion radial velocity increase, and the wall corrosion increases.

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Fig. 1. Magnetic field configuration and simulation area of Hall thruster

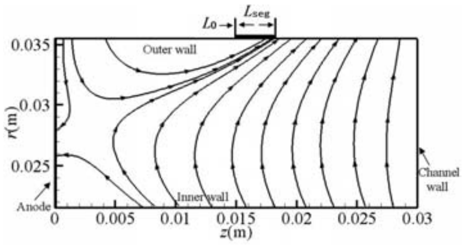

Fig. 2. Axial distribution of potential with different magnetic field configuration