§ 45. An Investigation of Spacecraft-Plasma Interactions
— Plasmas near the Thruster —

Nejoh, Y.N. (Hachinohe Institute of Technology)
Sanuki, H.

The electric propulsion for space vehicles utilizes electric and magnetic fields to accelerate a propellant to a much higher velocity than chemical propulsion does, and, as a result, the required propellant mass is reduced. Among electric propulsion devices Hall thrusters offer much higher thrust density than conventional ion thrusters. Hall thrusters have a merit that it accelerates a quasineutral plasma, and hence is not subject to a space-charge limit on the electric current. The impeded electrons can ionize the propellant neutral atoms effectively and support a significant axial electric field with equipotentials along the magnetic field lines. The axial electric field accelerates the ions from the anode towards the channel exit, in a direction that is opposite to the axial direction of the electrons. Hall thrusters have enjoyed both experimental and theoretical progress, however they remain far from a fully understood behavior. At present, modeling cannot be used for designing optimized structures in a fully confident way. Even if the basic idea is a rather simple one, the behavior of such discharges is complex and an improved understanding in terms of physics and modeling remains required. However, there is still no model describing adequately plasma dynamics inside the accelerating channel. The importance of developing a reliable model that improves our understanding of the factors which control plasma structure becomes evident when we attempt to improve upon existing Hall thruster designs, particularly regarding the instability of the discharge current, the thrust and the efficiency of the thruster.

When we discuss the discharge for the production of the plasma, the instability of the discharge current has frequently been reported[1]. We assume that the Xenon gas is injected into the channel and that the plasma components are electrons, Xenon ions and neutrals. Equations (1) and (2) are the conservation law of positive ions and neutral particles with the creation (positive sign) and annihilation (negative sign) terms of the right-hand side, respectively, where γ is the coefficient of the creational velocity of ions. In the channel of the thruster, ions increase due to the creation and neutrals decrease by the ionization.

$$\frac{\partial n_i}{\partial t}+\frac{\partial v_i}{\partial x}n_i=+\gamma n_i n_n \quad , \qquad (1)$$

$$\frac{\partial n_n}{\partial t}+\frac{\partial v_n}{\partial x}n_n=-\gamma n_i n_n \quad , \qquad (2)$$

where n_i, n_n, v_i, v_n, x, $\gamma = v_R\sigma = \lambda\nu\sigma$ are the ion and neutral densities, ion and neutral velocities, the distance from the anode and the creation rate of ions, respectively. Here, $\sigma=\pi r^2, \lambda, \nu$, $v_R=v_i-v_n$ denote the cross section of the collision, mean free path, the collisional frequency and the relative velocity between ions and neutrals, respectively. In this case, the period 0.00011s and the frequency 9.1kHz are obtained from Fig.1.

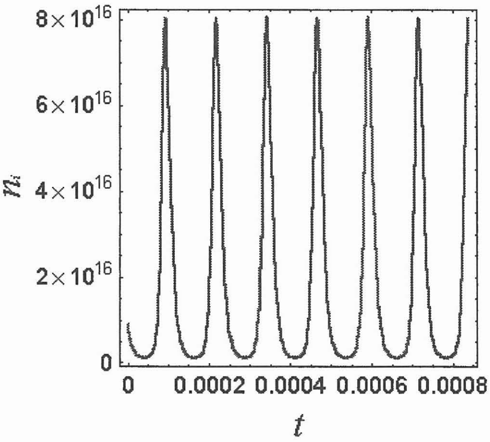

Fig.1. Oscillation of the ion density depending on time

We perform the simulation of the oscillation of the density and the ion current on the discharge ionization, and compare our results with the experimental ones[2]. Since the frequency and the electric current obtained here coincide with the previous ones, our model interprets the instability of the ion current shown in experimental results. We therefore show that when we decrease the cross-sectional area of the channel, the discharge current becomes stable. Moreover, it is pointed out to understand the basic features of the plasma is significant. This investigation thus offers the findings on the stabilization of the discharge instability associated with the ion-neutral collision in the Hall thruster of the spacecraft.

References
[1] Fife,J.M., Martinez-Sanchez,M and J.Szabo, 33rd AIAA/ASEM/SAE/ASEE Joint Propul. Conf. p.1 (1997).
[2] Mitsuboshi,M. and Nejoh,Y.N., Proc. 46th Space Sci. Tech. Symp. (CRL, Tokyo), p.147(2002).