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Effect of pressure on plasma sheath in a magnetic field

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Abstract

The effects of collisions on plasma sheath in an external magnetic field have been investigated by considering the collisions between ions and neutral gas atoms. The ion fluid equations containing an external magnetic field and the collisions are solved numerically to study the ion dynamics under various pressures.

Keywords: Magnetic sheath; Plasma; Collision; Ion dynamics

1. Introduction

In the past several years, many theoretical and experimental researches have been worked out for studying of plasma sheath [1–12]. Recently, some correlative works are developed to investigate the effects of magnetic field on the structure of the plasma sheath [6–9]. For example, Zou et al. [9] have shown that the characteristics of the plasma sheath in an oblique magnetic field cannot be ignored compared to the electrostatic field. They investigated the structure of the plasma sheath in an external magnetic field without considering the effect of collision. It is shown that considering an external magnetic field makes some fluctuations in ion flow velocity and density distribution. These fluctuations strongly depend on the component of magnetic field in depth direction; bigger the angle between the magnetic field and depth direction, more obvious the fluctuations. Here we study this dependency without ignoring the collisions between the ion and the neutral gas atoms. By using the fluid method, the ion fluid equations coupled with the Boltzman approximation for the electrons and Poisson equation are solved numerically without ignoring the collision force in the momentum equation. By using the numerical results, the effect of magnetic field on ion dynamics in a collisional magnetic sheath are investigated under various pressures.

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2. Simulation model

We consider a collisional plasma sheath in an external magnetic field. The plasma sheath has one-dimension coordinate space and three-dimension speed space, like the correlative works [8–12]. Also we assume that the physical parameters change with depth direction (z-direction) and the magnetic field embedded in xz plane and measure angle θ with respect to z-direction (see Fig. 1).

The ions are treated as a cold fluid governed by the number equation:

$$\frac{\partial}{\partial z}(n_i v_z) = 0. \tag{1}$$

And the momentum equation including collisions:

$$v_z \frac{\partial \vec{v}}{\partial z} = -\frac{e}{m_i}\vec{\nabla}\phi + \vec{v} \times \vec{\omega}_c - v_i \vec{v}, \tag{2}$$

where n_i, $\mathbf{v}$ and m_i are density, velocity and mass of ion respectively, $\omega_c = e\boldsymbol{B}/m_i$ is the ion cyclotron angular velocity and v_i is the effective ion collision frequency. In general, the ion collision frequency is a function of the ion flow velocity in depth direction, v_z. Here, we consider the ion collision frequency as a linear function of the v_z. Thus, v_i can be expressed as $v_i = \alpha v_z/\lambda_D$, where λ_D is electron Debye length and α is a dimensionless parameter. Since in the model α value characterizes the ion collision frequency which depends on the pressure, the numerical calculations are done under various α values to study the effect of