§9. Kinetic Effect on Plasma Coherent Structure Dynamics

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Recent papers have reported that the density profile in the far scrape-off layer (SOL) in magnetic confinement fusion devices is flatter than the exponential distribution which is expected from a diffusion model[1]. Motivated by these experiments, some authors have studied SOL plasmas theoretically. Then a theory of plasma blob dynamics has been suggested as the mechanism of the non-diffusive (convective) radial transport[2]. The plasma blob is a filamentary coherent structure along the magnetic field line, appears intermittently, and propagates from the edge of core plasma to the first wall. Such a structure is believed to transport a plasma into the far SOL across magnetic field lines. Many pieces of evidence that such structures are produced have been reported[3]. Further, many authors have investigated dynamics of blobs on the basis of two-dimensional reduced fluid models[3]. In such kind of macroscopic models, however, kinetic effects, such as sheath formation between plasma and divertor plate and velocity difference between ions and electrons, are considered under some assumptions and treated as some adjustable parameters. Thus, in this study, we investigate kinetic effects on blob dynamics with a three dimensional electrostatic plasma particle simulation[4, 5].

Figure 1 shows the configuration of the particle simulation. An external magnetic field is pointing into the z direction (corresponding to the toroidal direction). The strength of magnetic field increases in the positive x direction (corresponding to the counter radial direction) as $2L_xB_0/(3L_x - x)$ where L_x, L_y, and L_z are the system size in the x, y, and z directions and B_0 is the magnetic field strength at $x = L_x$. Particle absorbing boundaries are placed at $x = 0$ as the shaded planes shown in Fig. 1. The plane at $x = 0$ corresponds to the first wall. In the y (corresponding to the poloidal direction) and z directions, periodic boundary condition is applied. A coherent structure is initially set as a column along the external magnetic field (as shown in Fig. 1). The initial density configuration of the structure in the cross section is given by the Gaussian distribution with the width δ_b. The system size $L_x \times L_y \times L_z$ is $64\lambda_{De} \times 64\lambda_{De} \times 16\lambda_{De}$. The initial radius of the structure is $\delta_b = 4.0\lambda_{De}$.

Figure 2 shows the electron density distributions in the x-y plane at $z = L_z/2$ at $\omega_{pe}t = 800$ where the ion-to-electron temperature ratio is $T_i/T_e = 0.25$ and the magnetic strength is set as $|\Omega_e|/\omega_{pe} = 10$, 5, and 1 in the upper, middle, and bottom panels, respectively. As shown in Fig. 2, the symmetry breaking in a blob profile occurs when the magnetic strength is decreased. This fact is thought to indicate that the effect of Larmor radius induces the symmetry breaking.

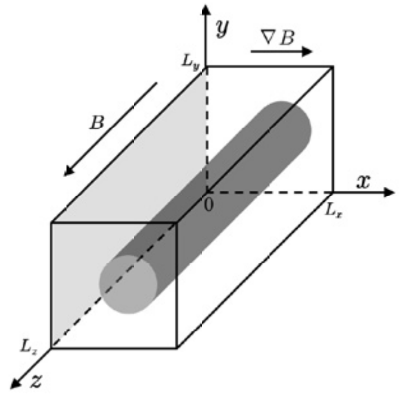

Fig. 1: Configuration of the simulation.

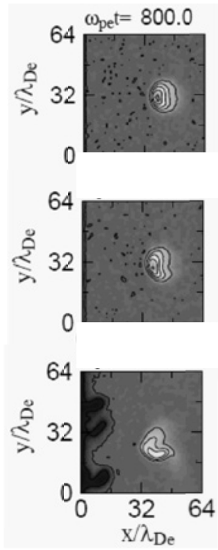

Fig. 2: Electron density distributions in the x-y plane at $z = L_z/2$ at $\omega_{pe}t = 800$ where the magnetic strength is set as $|\Omega_e|/\omega_{pe} = 10$, 5, and 1 in the upper, middle, and bottom panels, respectively.

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