§23. Development of Holistic Simulation Model for Plasma Coherent Structures

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Recently, it is reported that filamentary coherent structures are formed intermittently in non-uniform plasma such as scrape-off layer (SOL) of magnetic confinement fusion devices[1]. In such kind of structure, microscopic mechanics such as sheath formation between plasma and divertor plate, charge separation, and instability induced by shear flow are believed to have an influence on macroscopic dynamics. Thus, the purpose of this study is the development of a holistic code which connects microscopic mechanics with macroscopic dynamics and computes such a hierarchy system self-consistently. First, as an initial stage of the study, we have developed a three dimensional electrostatic plasma particle code[2] and investigated microscopic mechanics in such structures with the code.

In Fig. 1 we present the configuration of the simulation. An ambient magnetic field is directed along the positive z axis (equivalent to the toroidal direction). The strength of magnetic field has a gradient along the positive x axis (equivalent 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 boundary is 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 (equivalent 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}. A more detailed description of parameters is shown in Ref. [3].

Figure 2 shows electron density distributions in the x-y plane at $z = L_z/2$ at $\omega_{\mathrm{pe}}t = 100$, 800, 1,500, 2,200, and 2,900 where the system size $L_x \times L_y \times L_z$ is $64\lambda_{\mathrm{De}} \times 64\lambda_{\mathrm{De}} \times 16\lambda_{\mathrm{De}}$. The initial radius of the structure is $\delta_{\mathrm{b}} = 4.0\lambda_{\mathrm{De}}$. The structure is initially located at around $(x, y) = (48\lambda_{\mathrm{De}}, 32\lambda_{\mathrm{De}})$. As shown in Fig. 2, the structure evolves to a mushroom-shaped profile. This fact is in agreement with previous result of the two-dimensional reduced fluid model simulations[4].

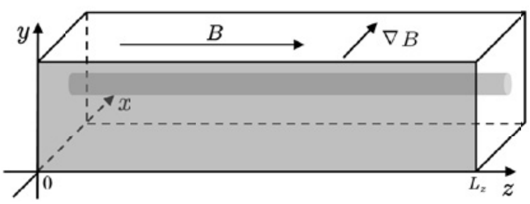

Fig. 1: Configuration of the simulation.

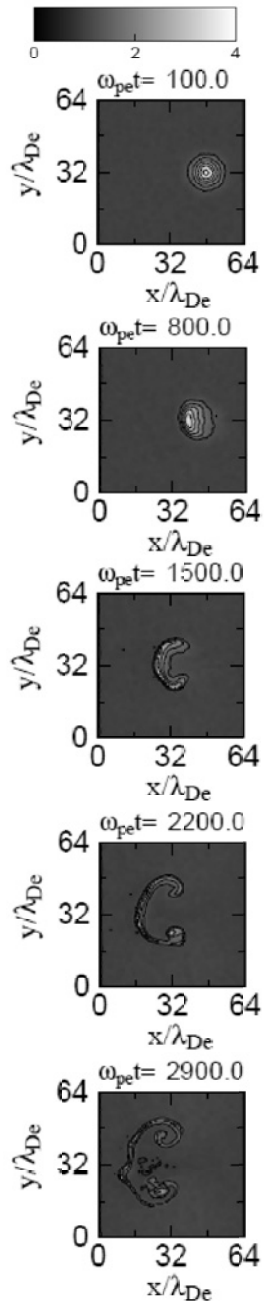

Fig. 2: Electron density distributions in the x-y plane at $z = L_z/2$ at $\omega_{\mathrm{pe}}t = 100$, 800, 1,500, 2,200, and 2,900.

1) Krasheninnikov, S. I. et al.: J. Plasma Phys. **74** (2008) 679 and references therein.

2) Ishiguro, S. and Hasegawa, H.: J. Plasma Phys. **72** (2006) 1233.

3) Hasegawa, H. and Ishiguro, S.: Plasma Fusion Res. **7** (2012) 2401060.

4) Bian, N. et al.: Phys. Plasmas **10** (2003) 671.