§29. Particle Simulation of Plasma Blob Dynamics

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Recently, it is reported that long-lived coherent structures "blobs" in scrape-off layer (SOL) of magnetic confinement fusion devices[1] propagate from the edge of core plasma to the first wall. Blobs are believed to transport a plasma into the far (second) SOL across magnetic field lines. Many theoretical and numerical works based on two-dimensional reduced fluid models have been performed and dynamics of blobs have been investigated[1]. In this kind of macroscopic model, kinetic effects, such as sheath formation between plasma and divertor plate, are treated under some assumptions and parameterization.

In this study, we have developed a three dimensional electrostatic plasma particle code with particle absorbing boundaries[2] for the purpose of investigating blob dynamics including kinetic effects. Configuration of the simulation is as follows. An external magnetic field is pointing into the z direction. The strength of magnetic field increases in the positive x direction. Particle absorbing boundaries corresponding to divertor plates are placed in the both ends of z axis. A particle absorbing boundary corresponding to the first wall is also placed at $x = 0$. In the y direction, periodic boundary condition is applied.

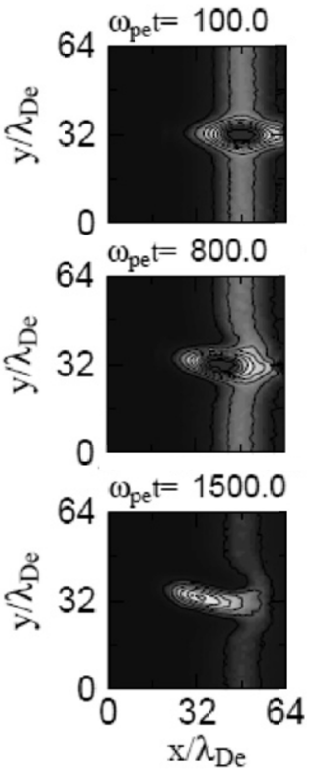

Fig. 1: Propagation of a blob.

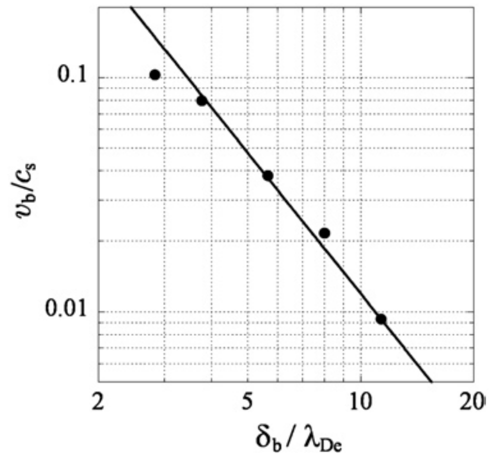

Fig. 2: Relation between the size of the blob and the propagation velocity of the blob.

Figures 1 and 2 were obtained from results of preliminary simulations. Figure 1 shows the electron density distribution in the x-y plane at $z = L_z/2$ at $\omega_{\rm pe}t = 100$, 800, and 1,500, where the system size $L_x \times L_y \times L_z$ is $64\lambda_{\rm De} \times 64\lambda_{\rm De} \times 256\lambda_{\rm De}$ and $\lambda_{\rm De}$ is the Debye length. The blob is initially located as a column along the external magnetic field at around $(x, y) = (48\lambda_{\rm De}, 32\lambda_{\rm De})$. Then, the blob moves to the first wall across the magnetic field lines. The mechanism of the blob propagation is as follows. Ions and electrons drift in the positive and negative y direction due to grad-B drift, respectively. Thus, an electric field in the negative y direction in the blob is formed. As a result, the blob moves in the negative x direction due to $E \times B$ drift[1].

Figure 2 shows the relation between the effective width of the blob in the y direction ($\delta_{\rm b}$) and the propagation velocity of the blob ($v_{\rm b}$), where $c_{\rm s}$ is the ion acoustic speed. In Fig. 2, the closed circle refers to results of simulations and the solid line represents

$$v_{\rm b}(\delta_{\rm b}) = v_{\rm b}^{\rm sim}(8\sqrt{2}\,\lambda_{\rm De}) \left(\frac{8\sqrt{2}\,\lambda_{\rm De}}{\delta_{\rm b}} \right)^2, \qquad (1)$$

where $v_{\rm b}^{\rm sim}(8\sqrt{2}\ \lambda_{\rm De})$ is the propagation velocity observed in the simulation in which the initial blob size is given as $\delta_{\rm b} = 8\sqrt{2}\,\lambda_{\rm De}$. From the theory based on the two-dimensional reduced fluid model, it was found that the blob propagation velocity is proportional to $\delta_{\rm b}^{-2}$[1, 3]. Figure 2 indicates that the particle simulation results are consistent with the fluid theory.

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) Krasheninnikov, S. I.: Phys. Lett. A **283** (2001) 368.