25G09

Study of Blob Dynamics with Particle Simulation
粒子シミュレーションによるブロブ挙動の研究

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A three dimensional electrostatic plasma particle code has been developed to study blob dynamics including kinetic effects. Some results of preliminary simulations coincide with previous results from two-dimensional reduced fluid model. The relation between observed blob propagation speed and initial blob size is consistent with the expectation by the fluid theory. The collapse of blob structure by certain instability is also observed.

1. Introduction

Recently, it was reported that the evidence of non-diffusive plasma transport from the edge of core plasma to the first wall in magnetic confinement fusion devices was observed. Such a transport is thought to be brought by long-lived coherent structures “blobs” in scrape-off layer (SOL) [1]. Blobs propagate across magnetic field lines and are believed to transport a plasma into the far SOL. Many theoretical and numerical studies of blobs have been performed on the basis of two-dimensional reduced fluid models and dynamics of blobs have been investigated [1]. However, kinetic effects, such as sheath formation between a SOL plasma and a divertor plate, are treated under some assumptions and parameterization in that kind of macroscopic model.

In this study, we have developed a three dimensional electrostatic plasma particle code with particle absorbing boundaries [2] in order to study blob dynamics including kinetic effects. Results of preliminary simulations indicate that blobs move to the first wall across the magnetic field lines. Obtained relation between the observed propagation speed of the blob and the initial effective width of the blob in the poloidal direction is consistent with the expectation by the fluid theory. In no sheath case, it is observed that a blob evolves to a mushroom-shaped object. This fact is in agreement with previous results of the fluid model simulations [3].

2. Simulation Method

We use a three-dimensional electrostatic particle code with full particle dynamics to investigate blob propagation. Configuration of the simulation is as follows. An external magnetic field is pointing into the z direction (equivalent to the toroidal direction). The strength of magnetic field increases in the positive x direction (equivalent to the counter radial 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 (equivalent to the poloidal direction), periodic boundary condition is applied. The schematic figure of the simulation system is shown in Fig. 1. The shaded planes in Fig. 1 refer to absorbing boundaries.

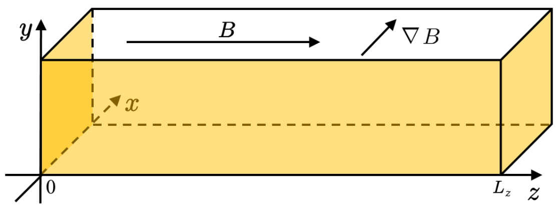

Fig. 1. Configuration of the simulation

3. Results of preliminary simulations

We now show results of preliminary simulations. Figure 2 displays electron density distributions in the x-y plane at $z = L_z/2$ at $\omega_{pe} t$ = 100, 800, and 1,500, where the system size $L_x \times L_y \times L_z$ is 64 λ_{De} x 64 λ_{De} x 256 λ_{De} and λ_{De} is the Debye length. The blob is initially located as a column along the ambient magnetic field at around (x, y) = (48 λ_{De}, 32 λ_{De}). This figure indicates that the blob moves to the first wall across the magnetic field lines as the

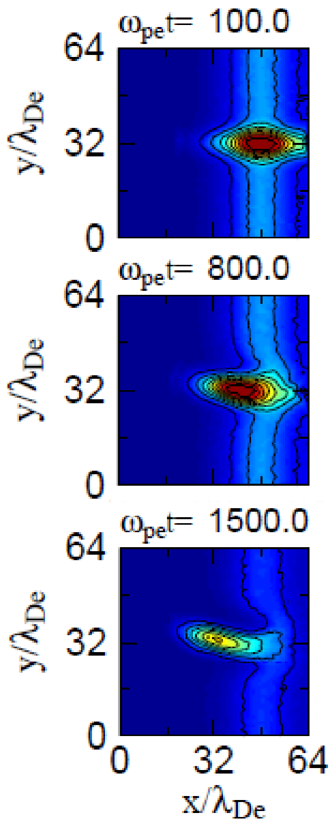

Fig. 2. Electron density distribution at ω_{pe} t = 100, 800, and 1,500

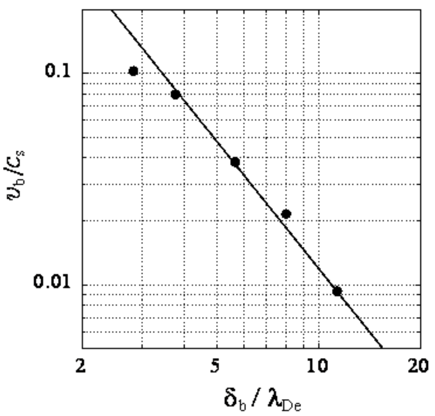

Fig. 3. Relation between blob size and blob propagation speed

fluid model expected.

We show in Fig. 3 the relation between the effective width of the blob in the y direction (δ_b) and the propagation velocity of the blob (v_b), where c_s is the ion acoustic speed. In Fig. 3, the closed circle refers to results of simulations and the solid line represents

$$v_b(\delta_b) = v_b^{\mathrm{sim}}(11.3\lambda_{De})\left(\frac{11.3\lambda_{De}}{\delta_b}\right)^2, \qquad (1)$$

where v_b^{sim} (11.3 λ_{De}) is the propagation speed observed in the simulation in which the initial blob size is given as $\delta_b = 11.3\ \lambda_{De}$. From the theory based on the two-dimensional reduced fluid model, it was found that the blob propagation velocity is proportional to δ_b^{-2} [1, 4]. Thus, Fig. 3 indicates that the particle simulation results are consistent with the fluid theory.

On the other hand, Fig. 4 gives a result in the case that periodic boundary condition is applied in the z direction, i.e., there is no sheath. As shown in Fig. 4, the blob evolves mushroom-shaped structure by certain instability. This fact is in agreement with previous results of the two-dimensional reduced fluid model simulations [3].

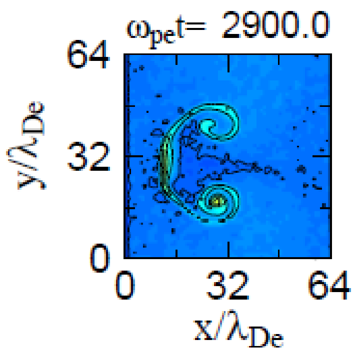

Fig. 4. Electron density distribution obtained by simulation in the case of no sheath

4. Summary

We have developed a three dimensional electrostatic plasma particle code to study blob dynamics including kinetic effects. We then showed results of preliminary simulations. Some results coincide with previous results from the fluid model.

The close investigation into the effect of kinetic dynamics on blob propagation will be one of topics in future work.

Acknowledgments

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