§22. Development of New Downstream Model for PASMO

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Magnetic reconnection plays an important role in plasmas, and leads to the fast energy release from magnetic field to plasmas and the change of magnetic field topology. We develop a three-dimensional PArticle Simulation code for Magnetic reconnection in an Open system (PASMO) [1,2,3]. At the open downstream boundary, particles can not only go out of but also come into the system across it. The problems in the downstream boundary condition of particles are how many particles come into the system, and how to assign the positions and velocities of these incoming particles. For the boundary condition of particles at downstream, we assume that the physical state outside is the same as that in the boundary region. This assumption means the zero normal derivative condition. Because PIC simulation has infinite information, there are many ambiguities in the way how to set up the boundary condition. Moreover, the velocity distribution function becomes a non-Maxwellian in the downstream region as a result of reconnection process. Accordingly, it is impossible that all of quantities satisfy the zero normal derivative condition, and that the distribution of incoming particles is assumed to be a Maxwellian. At least we have to select the boundary condition that the zeroth, first and second momenta should satisfy. In this paper we compare the simulation results for the short and long simulation boxes in order to check the validity of the new open downstream model.

The new open downstream model is as follows. X boundary cells are defined as the cells which are located at $x_b - \Delta x < |x| < x_b$, where x_b is the length of the simulation box and the Δx is the grid size along x direction. The cell is a parallelepiped whose length, width and height are Δx, $2y_b$ and $2z_b$, respectively (y_b and z_b are the half width and half hight of the simulation box). After the pusher process, the particles in X boundary cell and outside of simulation box are removed. In order to realize the above assumption, we make the same particle distribution function in X boundary cell as that in the neighbor cell of X boundary cell. From this definition, the derivatives of particle quantities along x direction are always vanished at the boundary. Accordingly, the zero normal derivative condition is realized there.

Figure 1 shows the snapshots of magnetic field in the cases of the short and long simulation boxes at $t\omega_{ce} = 680$. The short current sheet ($25.4\rho_i$) is set up in the short-simulation box, while the very long current sheet ($102\rho_i$) in the long-simulation box, where ρ_i is the ion Larmor radius. The driven reconnection takes place at center of the simulation box both for the short and long simulation boxes. It is found that the magnetic field structure in the case of short simulation box is consistent with that in the case of long simulation box. Finally we compare them quantitatively. Figure 2 displays the profile of frozen-in condition $\boldsymbol{E}+\boldsymbol{u}\times\boldsymbol{B}$ along x direction passing X point. The positions of peaks and tendency of every quantity in the case of short simulation box are in good agreement with those in the case of long simulation box.

They means that the results of short-simulation box mimic the corresponded part of long-simulation box, and that the open downstream boundary model works very well. Using this boundary model, we succeed in increasing the accuracy of simulation.

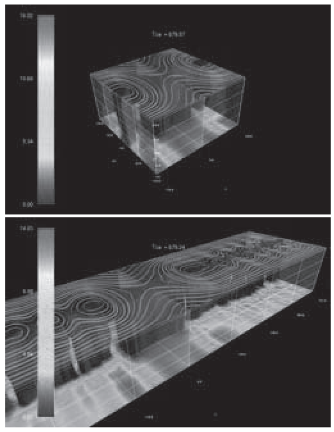

Fig. 1. Snapshot of magnetic structure at $t\omega_{ce} = 680$. Top and bottom figures show the results of the short and long simulation boxes, respectively. Isoline on top plane shows the magnetic flux ϕ, and isosurface and contour on the bottom plane show $B_x^2 + B_y^2$.

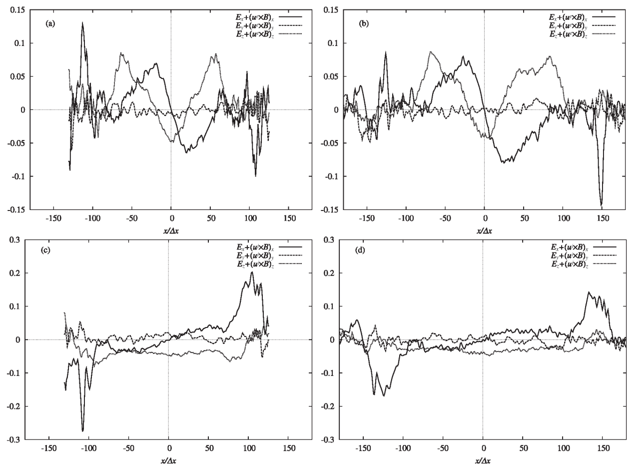

Fig. 2. Profile of $\boldsymbol{E}+\boldsymbol{u}\times\boldsymbol{B}$ along x direction. Left and right figures show the cases of short and long simulation boxes, respectively. Top and bottom show the cases of electron and ion, respectively. Solid, dashed and dotted lines show x, y and z components of $\boldsymbol{E}+\boldsymbol{u}\times\boldsymbol{B}$, respectively. In the case of long simulation box, the region which corresponds to the short simulation box is enlarged.

1) Pei, W. et al.: Phys. Plasmas, **8**, 3251 (2001).
2) Ohtani, H. et al: LNCL, **4759**, 329 (2008).
3) Ohtani, H. et al: submitted to JCP.