

## §20. Structure of Ion Dissipation Region of Driven Reconnection in An Open System

Ohtani, H., Horton, W. (Univ. Texas at Austin), Horiuchi, R.

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]. Ions become un-magnetized and execute a complex thermal motion called meandering motion in the ion dissipation region. The complex meandering (chaotic) motion leads to the growth of off-diagonal components of pressure tensor term, which is a main cause to break ion frozen-in condition in the vicinity of magnetic neutral sheet [3]. In this paper we investigate the role of the meandering motion in the formation of ion dissipation region by examining particle simulation results of collisionless driven reconnection based on the following simple model.

Figure 1 shows the spatial profiles of magnetic field ( $B_x$  and  $B_y$ ) at the steady state. Because  $B_x$  and  $B_y$  change linearly in the vicinity of the reconnection point ( $x = 0$  and  $y = 0$ ), the magnetic field can be written as

$$B_x = B'_x y, B_y = B'_y x, \quad (1)$$

where  $B'_x$  and  $B'_y$  are constant. Using these equations, the local ion Larmor radius  $\rho_L$  is written as

$$\rho_L(x) = \frac{mv_\perp}{eB_y} \simeq \frac{mv_{th}}{eB'_y x}, \quad (2)$$

$$\rho_L(y) = \frac{mv_\perp}{eB_x} \simeq \frac{mv_{th}}{eB'_x y}, \quad (3)$$

where  $v_{th}$  is the thermal velocity. The spatial size  $L_{mi}$  of the meandering motion is determined from the location which satisfies the relation [1]

$$L_{mi} = \rho_L(L_{mi}). \quad (4)$$

If the size of the dissipation box is equivalent to the meandering motion amplitude, the length  $x_c$  and width  $y_c$  are obtained from Eqs. 1, 2, 3 and 4 as

$$x_c^2 = \frac{m_i v_{th}}{e B'_y}, \quad (5)$$

$$y_c^2 = \frac{m_i v_{th}}{e B'_x}. \quad (6)$$

These  $x_c$  and  $y_c$  are shown in Figs. 1 and 2.

Next we discuss the relation between the width  $y_c$  of dissipation region and the ion pressure tensor  $\Pi^i$ . Figure 2 shows the profiles of terms of the force balance equation for ion

$$E_z + (u^i \times B)_z = \left\{ \frac{\partial}{\partial t} + (u^i \cdot \nabla) \right\} u_z^i + \frac{1}{en^i} \nabla \cdot \Pi^i, \quad (7)$$

where  $u^i$  is ion flow velocity. It is found that the pressure tensor term  $\frac{1}{en^i} \frac{\partial \Pi_{yz}^i}{\partial y}$  mainly supports the electric field  $E_z$  around the reconnection point ( $x = 0$ ). Let us consider writing down  $\frac{1}{en^i} \frac{\partial \Pi_{yz}^i}{\partial y}$  as a function of  $y$ . The pressure tensor  $\Pi_{yz}^i$  is approximately given by

$$\Pi_{yz}^i \sim \int dv m^i v_y v_z f^i, \quad (8)$$

where  $f^i$  is the distribution function. Because the velocity  $v_y$  and  $v_z$  are given by  $E \times B$  drift and thermal velocity  $v_{th}$  in the outside of dissipation region ( $|y| > y_c$ ) respectively,

$$\Pi_{yz}^i \sim \frac{m^i n^i E_z B_x v_{th}}{B_x^2 + B_y^2}. \quad (9)$$

Because  $B_x$  also changes linearly in  $|y| > y_c$  (Fig. 1(b)), we can substitute Eq. 1 into Eq. 9. The pressure tensor term in Eq. 7 is given by

$$\frac{1}{en^i} \frac{\partial \Pi_{yz}^i}{\partial y} = -\frac{1}{en^i} \frac{m^i n^i E_z B'_x v_{th} (B_x'^2 y^2 - B_y^2)}{(B_x'^2 y^2 + B_y^2)^2}. \quad (10)$$

This analytic solution is drawn in Fig. 2. It is clear that the tendency of this solution is in agreement with that of the simulation result. When we substitute  $y_c$  into  $y$  in Eq. 10 and ignore the term  $B_y$  because  $B_x \gg B_y$ , Eq. 10 is reduced to  $-E_z$ . In concluding, we can make sure that the ion orbit effect controls the physics in the ion dissipation region from this simple analysis.

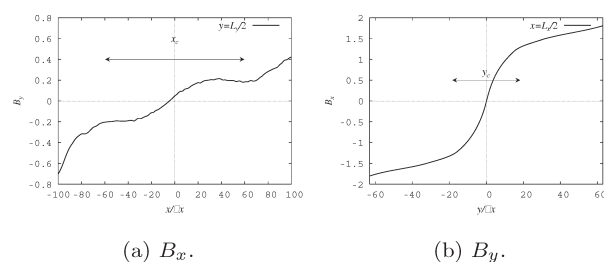


Fig. 1. Spatial profiles of magnetic field at the steady state ( $t\omega_{ce} = 806$ ). (a)  $B_x$  along  $y$  direction and (b)  $B_y$  along  $x$  direction.  $L_x$  and  $L_y$  are the simulation box sizes.

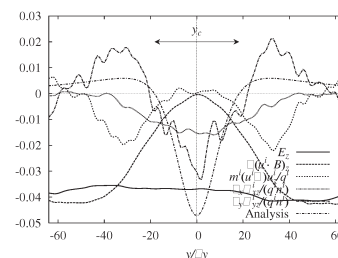


Fig. 2. Width of dissipation region and spatial profiles of force balance at the steady state.

### Reference

- 1) Pei, W. et al.: Phys. Plasmas, **8**, 3251 (2001).
- 2) Ohtani, H. et al: LNCL.
- 3) Ishizawa, A. and Horiuchi, R. : PRL, **95** 045003-1 (2005).