§19. Three-dimensional Evolution of Ion-scale Current Sheet in Collisionless Driven Reconnection

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The dynamical evolution of ion-scale current sheet in collisionless driven reconnection is investigated by using an electromagnetic particle simulation code (``PASMO") [1,2,3,4,5]. The simulation starts from the Harris equilibrium. Driving electric field, which is imposed in z direction at the upstream boundary, creates the plasma inflow towards the central region and compresses the current sheet. When the current sheet size becomes comparable to the ion kinetic scale, collisionless reconnection sets in due to kinetic processes. The current sheet structure is gradually changed from the Harris equilibrium to a new kinetic one. A kinetic regime appears in the central current sheet, in which frozen-in condition is broken due to kinetic processes. Because the scale size of un-magnetization region is different between ions and electrons, the kinetic regime is separated into two dissipation regions with different spatial scales, i.e., ion dissipation region (IDR) and electron dissipation region (EDR) [1,4,5].

Figure 1 shows the spatial profiles of electron forces in the inflow direction (y direction) and normalized charge density in a steady state. The ions are un-magnetized inside IDR, while electrons are still magnetized there. The driving electric field acts mainly on magnetized electrons and pushes them into EDR with the $\mathbf{E}\times\mathbf{B}$ drift velocity. The inward electrostatic field is generated due to the resultant charge separation, as shown in Fig. 1. The electrostatic field grows largely so as to balance with the convective electric field $\mathbf{v}_e\times\mathbf{B}$ which is almost the same as the Hall electric field. It is noted in Fig. 1 that the pressure-gradient term is negligibly small compared with the electric field although the compression may give rise to the steep gradient in the electron pressure (we have confirmed that this is true in two-dimensional case).

The electric current density Jz increases through the acceleration by reconnection electric field Ez near the reconnection point, which is located at the center of current sheet. The growth of relative plasma flow between ions and electrons triggers a plasma instability called the drift kink instability (DKI) with a wave number in the z direction. Figure 2 illustrates the spatial profiles of y-z component of electron pressure tensor in the y-z plane, which is dominant over the other components. As soon as the current sheet is compressed below the ion kinetic scale, DKI starts to grow inside EDR first. Three-dimensional modification appears in the electron pressure tensor, as shown in Fig. 2. However, the ion pressure tensor remains almost unchanged then. The average of the electron pressure tensor over the periodic direction (z direction), <Peyz>, decreases owing to the growth of wave structure. It becomes negligibly small when the wave component becomes dominant in the pressure tensor, as shown in the right panel of Fig. 2. This is because the electron pressure force term becomes negligibly small in EDR even in the relatively early phase. Thus, he electrostatic force balances with the Lorentz force $\mathbf{J}_e\times\mathbf{B}$ in the inflow direction.

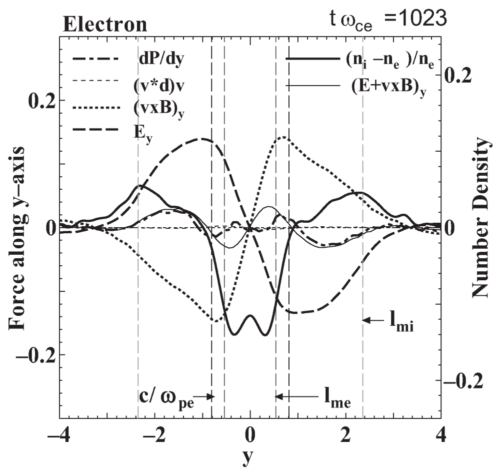

Fig. 1. Spatial profiles of electron forces in the inflow direction and normalized charge density at $\omega_{ce}t$ =1023.

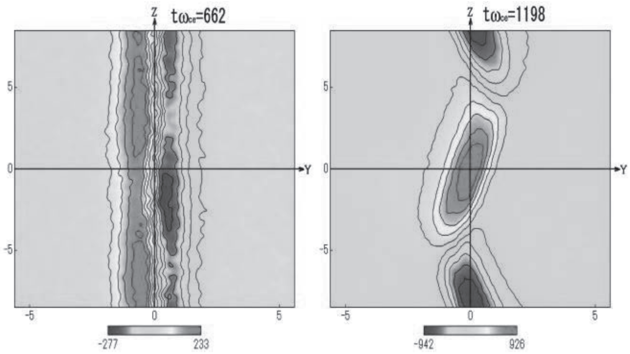

Fig. 2. Spatial profiles of y-z component of electron pressure tensor in the y-z plane at $\omega_{ce}t$=662 (left) and 1198 (right).

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