§20. Conversion Process of Electron Kinetic Energy in the Electron Dissipation Region in Steady Collisionless Driven Reconnection

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The dynamical evolution of collisionless driven reconnection is investigated by using the electromagnetic particle simulation code ("PASMO") developed for a microscopic open system which is surrounded by an external macroscopic system [1,2,3,4]. The analysis of the present study is focus on the conversion process of the electron kinetic energy in the electron dissipation region along outflow direction (x direction).

The electron dissipation region appears in the central region of the current layer where electron frozen-in condition is broken through electron kinetic effects and the electron current density grows largely. The electron dissipation region has a two-scale structure along the x direction [5]. At the reconnection point which is located at the center of the electron dissipation region, the acceleration mechanism works effectively for electrons as well as the heating. However, the acceleration by the reconnection electric field is so strong that the electron average velocity in equilibrium current direction (z direction) reaches the electron Alfven velocity. Figure 1 shows the spatial profiles of two components of the electron kinetic energy in a steady state. The z component of electron kinetic energy maximizes and the x component minimizes at the reconnection point. As the flow moves towards the inner outflow edge of the electron dissipation region at which the outflow component of electron kinetic energy maximizes, the z component of the electron kinetic energy decreases, while the x component increases.

The electron equation of energy along the outflow direction can be written as

$$\frac{d}{dt}(\frac{1}{2}mv_x^2) = -e(E_x \cdot v_x - \frac{v_z \cdot B_y \cdot v_x}{c}), \qquad (1)$$

$$\frac{d}{dt}(\frac{1}{2}mv_z^2) = -e(E_z \cdot v_z + \frac{v_x \cdot B_y \cdot v_z}{c}). \qquad (2)$$

The first term on RHS stands for the work done by the electric field, and the second term on RHS stands for the work done by the Lorentz force. Because the Lorentz force terms in Eqs. (1) and (2) are the same except their sign, they do not lead to the change in the total energy. It is noted in Fig. 1 that the summation of two components of the electron kinetic energy is kept to be almost constant from the reconnection point to the inner outflow edge of the electron dissipation region. This implies that the dominant component of electron kinetic energy changes from the z component to the x component through the work done by Lorentz force when electrons flow towards the inner outflow edge of the electron dissipation region. Thus, the work done by the electric field is relatively small there.

Figure 2 shows the electron distribution functions in the (x,v_x) and (x,v_y) spaces in the steady sate. The acceleration is dominant over the heating for electrons when they flow through the inner scale of the electron dissipation region, while the electron dissipation becomes dominant in the outer scale. It is concluded that, in the inner scale region, total electron kinetic energy is almost conserved and the electron kinetic energy is converted from the out-of-plane component to its outflow component by Lorentz force.

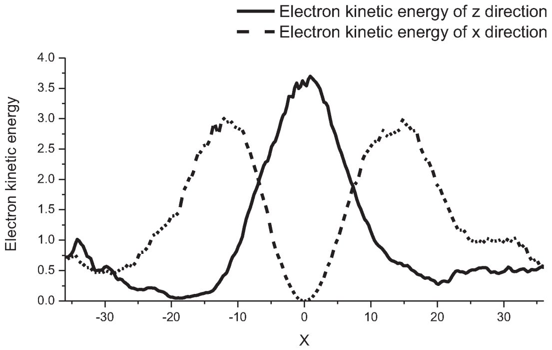

Fig. 1. Spatial profiles of the electron kinetic energy in the equilibrium current direction and the outflow direction along the outflow direction in the steady state.

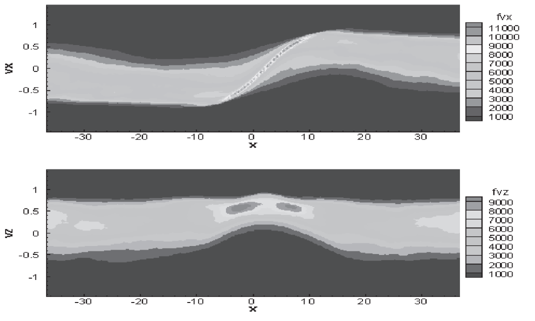

Fig. 2. The electron distribution functions in the x-v_x (top) and x-v_y (bottom) spaces in the steady state.

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