§22. Plasma Diffusion due to Microscopic Instabilities in a Thin Current Sheet

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Collisionless magnetic reconnection is one of the fundamental physical processes controlling to dynamic plasma phenomena in high temperature and low density plasmas. Instead of binary collisions, microscopic nonideal effect can violate frozen-in condition and cause collisionless magnetic reconnection in such systems. In our previous studies[1)], the force balance between wavy electric force and average magentic force ($\langle \tilde{n}\tilde{\mathbf{E}} \rangle \leftrightarrow \langle n\mathbf{v} \rangle \times \langle \mathbf{B} \rangle$) is observed to hold at the growing phase of Lower Hybrid Drift Instability(LHDI). In addition, the generation of DC electric field associated with wavy magnetic force ($\langle n \rangle \langle \mathbf{E} \rangle \leftrightarrow \langle \tilde{n}\mathbf{v} \times \tilde{\mathbf{B}} \rangle$) is observed to hold at the growing phase of Drift Kink Instability(DKI). These wavy force terms suggest the interaction between particles and the fluctuation of electromagnetic field. The detail of the dynamics of particles which interact with the instablities growing at current sheet such as DKI and LHDI is investigated by means of 2+1/2 dimensional explicit electromagnetic particle simulation.

In order to investigate the anomalous transport process in relation to these instabilities, energy spectra (Fig.1) and distribution functions are examined at some position around the neutral sheet. At the LHDI phase, number of low temperature electrons is reduced at the neutral sheet (y=0) and the LHDI region (y=L), while number of high temperature electrons increases at and outside of the LHDI region (y=L,1.67L), where L is inital scale length of current sheet. Thus, low energy electrons are transported outward with the energy conversion from electric waves due to LHDI. On the other hand, ions decrease at the neutral sheet and increase at the outside of neutral sheet independent of their energy. Ion energy spectrum does not change at y=L. Ions in the central region ($y < L$) are transported to the outer region ($y > L$) without any energy conversion from LHD wave. Only anisotropic deformation of distribution function takes place during the tranportation of ions. It suggests that the electrostatic field, which is generated as a result of the electron outward flow, forces ions to follow the electrons, and thus ions are also transported outward instead of direct interaction with LHD waves. Similar heating process is also observed at DKI growing phase. Although DKI has larger temporal and spatial scales such as the scales of ion gyration motion, particle heating through the wave-particle interaction takes place only for electrons. These properties are consistent with recent results of MRX reconnection experiments[2)]. More investigations are needed to clarify the roles of electron and ion kinetic effects in the interaction process between meandering particles and drift kink mode at the vicinity of neutral sheet.

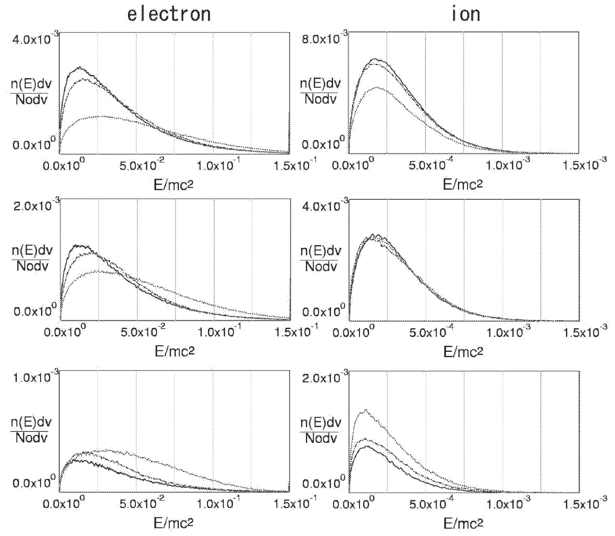

Figure 1: Energy spectrum of electron (left) and ion (right) at neutral sheet (top), y=L (middle) and y=2L (bottom). Solid, dashed and dotted lines stand for the profiles at initial, $t\omega_{ci} = 3.31$ (LHDI phase) and $t\omega_{ci} = 2.21 \times 10^1$ (DKI phase), respectively

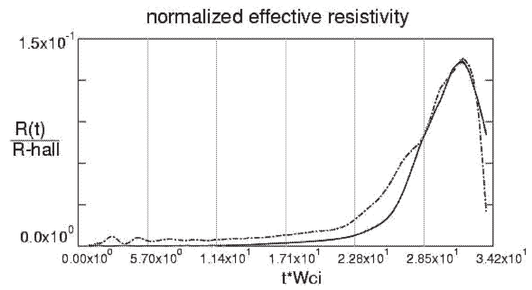

Figure 2: Temporal evolutions of normalized effective resistivity estimated by DC electric field (solid line) and by damping rate of current densities (dot-dashed line)

The outward transportation results in the dissipation of current density. Anomalous resistivity is estimated from the damping rate of the current density (Fig.2). The anomalous resistivity increaces in the linear growth phase of DKI consistent with the effective resistivity estimated from DC electric field which is balanced with wavy magnetic force term. The maxmun value of the resistivity is the same order as the effective resistivity observed in the particle simulation in driven reconnection in the plane along reconnection magnetic field[3)]. Thus the wave-particle interaction due to DKI observed in present simulation can create effective resitivity enough for triggering collisionless magnetic reconnecion.

References

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3) R.Horiuchi et al, Phys.Plasmas, **4**, 277(1996)