§24. Mass Ratio Dependence of Drift Kink Instability in the Current Sheet

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Collisionless magnetic reconnection at the cureent sheet structure with the reversed magnetic field is one of the fundamental physical processes connect to dynamic plasma phenomena in high temperature and low density plasmas such as the solar colona, the geomagnetic tail and fusion plasma. Instead of binary collisions, microscopic nonideal effect can violate frozen-in condition and cause collisionless magnetic reconnection in such systems.

The current sheet can be unstable against a variety of microscopic plasma instabilities. The excitation of these instabilities and their reletionship with magnetic reconnection are investigated by means of 2+1/2 dimensional explicit electromagnetic particle simulation. In the microscopic view of plasma, particle thermal motion with characteristic scale of lamor radius or meandering scale is important. Mass ratio is one of the parameters which determine these scales. The simulation is carried out for large mass ratio(mass ratio : 200,800) and the result is compared with previous case(small mass ratio : 25). Simulation with large mass ratio requires vast numerical costs to reslove spatial and temporal scale for both ions and electrons. We improve our simulation code by the optimal parallelization for SX7, to increase the speed of calculation about 20 times from previous simulation code. In addition, to prevent the effect of two-fluid stream instabilities for these instabilities, we set no background particles in the initial equilibrium by providing weak velocity shear near the boundary.

In each case, Lower Hybrid Drift Instability(LHDI)[1] and Drift Kink Instability(DKI) are observed to grow at the periphery of current sheet and neutral sheet, respectively. Qualitatively, the generation of the nonideal term is similar to small mass ratio case (Fig.1). In the DKI growing phase after the saturation of LHDI, DC electric field consistent with total magnetic flux reduction is generated and current density dissipates at neutral sheet. The wavy coupling term, which stands for wave-particle interaction, balances this DC electric field term. The growth of DKI creates nonideal anomalous resistivity, and the growth rate of DKI can control the reconnection rate and time scale of them.

In the linear theory of DKI[2] predicts that growth rate is reduced as mass ratio increases and DKI growth rate becomes quite small in realistic mass ratio. In the theory, the linear growth rate of DKI γ_{DKI} in the case of mass ratio $M_i/M_e = 200$ is about a tenth of that for $M_i/M_e = 25$, and γ_{DKI} in the realistic mass ratio case is reduced to 0.01 of that for $M_i/M_e = 25$. However, this decrease of the growth rate according to the mass ratio increase is considerably less in the results of the simulation (Fig.2). In the case of $M_i/M_e = 200$, the growth rate of DKI is more than half in that for $M_i/M_e = 25$. And the relaxation rate of current density of this case also remains a third of the relaxation rate of $M_i/M_e = 25$. Even in the case of quite larger mass ratio case of $M_i/M_e = 800$, the growth rate is about one-fifth for that in the case of $M_i/M_e = 25$. This larger-than-expected growth of DKI is considered to be due to the current sheet deformation by the nonlinear effect of LHDI[3]. These result sugget that the growth of DKI and the generation of anomalous resistivity can have a certain effect in triggering magnetic reconnection in realistic mass ratio case.

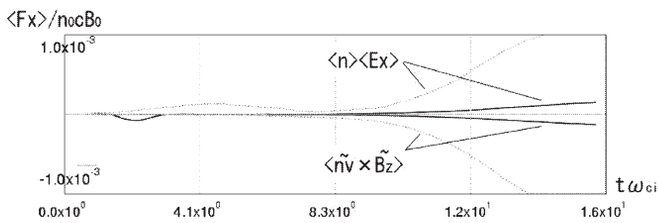

Figure 1: Time dependence of force balance between averaged electric field term and wavy component of magnetic force term ; mass ratio 25 (dashed lines) and mass ratio 200 (solid lines)

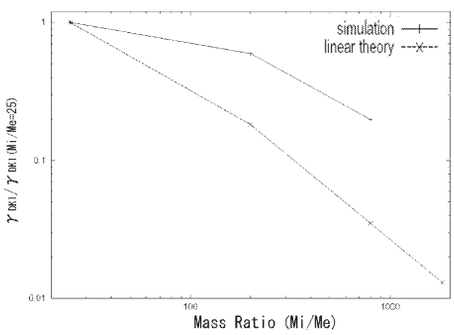

Figure 2: Mass ratio dependence of the growth rate of DKI in the simulation (+) and the theory calculated from 2)(×), where these rates are normalized by that for $M_i/M_e = 25$

References

1) R.C.Davidson et al, Phys.Fluids, **20**, 301(1977)
2) W.Daughton, Phys.Plasmas, **6**,1329(1999)
3) R.Horiuchi et al, Phys.Plasmas, **6**, 4565(1999)