§14. Self-generation of Hollow Current Profile in Field-Reversed Configurations

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The dangerous tilt instability in the field-reversed configuration (FRC) is predicted by the MHD theory, but it has not been observed in the experiments. Steinhauer and Ishida pointed out that most experimental equilibrium configurations tend to take a hollow current profile.[1] An MHD equilibrium was used as the initial condition for 3D EM particle simulation.[2] However, the influence of the kinetic effect on the tilt mode was not clarified in that simulation, because the MHD equilibrium relaxes to the kinetic one simultaneously with the evolution of the tilt instability. The purpose of this study is to investigate the relaxation process of the FRC plasmas from the MHD equilibrium to the kinetic one by 2D EM particle simulation.

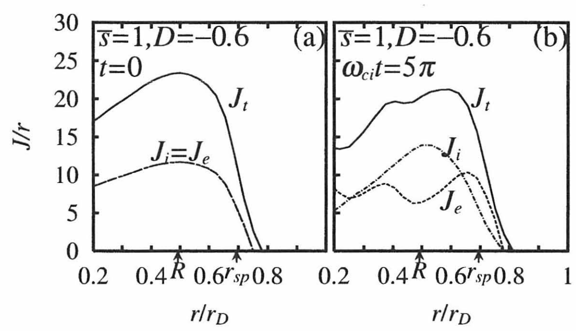

Fig. 1: Radial profile of toroidal current density for full kinetic case ($\bar{s} = 1$) at (a) $\omega_{ci}t = 0$ and (b)$\omega_{ci}t = 5\pi$, where $\omega_{\rm ci}$ is the ion cyclotron frequency, $\bar{s}$ is the FLR parameter D is the hollowness parameter, and r_D is the radius of the confinement vessel, respectively.

Through the relaxation from the MHD equilibrium to the kinetic one, the electron current density J_e decreases near the null line (R), and increases near the separatrix ($r_{\rm sp}$) shown in Fig. 1. An initial peaked profile changes to a hollow profile. On the other hand, the ion current density J_i becomes more peaked. So the total current J_t changes the hollow profile near the null line.

Both the decrease of J_e and the increase of J_i near the null line can be explained by the character of the single particle orbit. The dominant electron motion on the midplane is the gradient B drift. Because the gradient B drift has the opposite sign to the electron diamagnetic drift, J_e decreases near the null line (Fig. 2). On the other hand, when the spatial scale of magnetic field is almost the same as the ion orbit scale, ions execute meandering motions along a null line. The average toroidal velocity is so large due to the meandering motion that J_i increases near the null line. This explanation is confirmed in the calculation of the orbits of particles, which

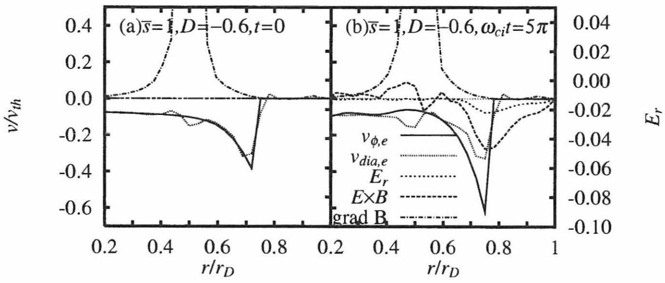

Fig. 2: Electron average toroidal velocity at (a) $\omega_{ci}t = 0$ and (b)$\omega_{ci}t = 5\pi$.

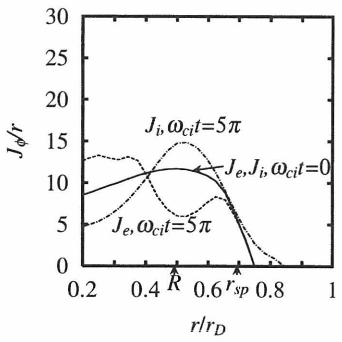

Fig. 3: Radial profile of toroidal current density in the orbit calculation for $\bar{s} = 1$ and $D = -0.6$.

satisfy the same initial conditions as 2D simulation, under the fixed field (Fig. 3). Due to only the effect of the single particle orbit, J_e decreases and J_i increases near the field-null line (R). Note that both J_i and J_e do not change near the separatrix ($r_{\rm sp}$). This tendency for the electron current to become hollow and for the ion current to become peaking near the field-null line is the same as the results of 2D simulation (Fig. 1).

Next, we examine why J_e increases near the separatrix. Since the density profile becomes steep locally in the narrow periphery region near the separatrix, the ion FLR effect generates the strong radial electric field E_r there (Fig. 2). Because the generated $E \times B$ drift has the same sign as the electron diamagnetic drift, J_e increases in the periphery. On the other hand, E_r acts on ions less effectively since the ion Larmor radius is larger than the spatial size of a strong electric field region. That is, the modification of ion current profile becomes relatively smaller.

In this way, an initial MHD equilibrium relaxes to a kinetic one with the electron hollow and ion peaked current profiles through the single particle orbit effect and ion FLR one.

Reference

1)Steinhauer, L. C. et al.: Phys. Fluids **B 4**, 645 (1992).
2)Nishimura, K. et al.: Phys. Plasmas **4**, 4035 (1997).