## §9. Nonlinear Saturation of Drift Kink Instability and Current Profile Flattening in FRC Plasmas

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A beam injection is considered as an effective method to keep FRC plasmas stable against the tilt mode [1]. However, three-dimensional particle simulation reveals that a peaked current profile with a strong beam component becomes unstable against the drift kink (DK) instability [2].

Figure 1 shows the radial distributions of the current density at three different time periods. The typical profile of the current density with a beam component has a sharp peak in the vicinity of the field-null line at the initial stage. The peaked current profile changes gradually towards the smoothed one as the DK instability grows up. It is observed that the DK instability is nonlinearly saturated when the initial peaked current profile of $L \ll \rho_{i0}$ relaxes to the smoothed profile of $L \geq \rho_{i0}$ ( $L$ is the half-width of current profile and $\rho_{i0}$ is the typical ion Larmor radius). That is, the ion beam which is localized in an unmagnetized narrow region ($L \ll \rho_{i0}$) spreads over the magnetized wide region ($L \geq \rho_{i0}$) as a result of the nonlinear evolution of the DK instability, and thus the ion magnetization effect can stabilize the DK mode.

In Fig. 2, the maximum saturation amplitude of the perturbed magnetic field is shown as a function of the beam velocity $v_b/v_{Ti}$ for the cases of $N_b/N_i = 0.01$ and $N_b/N_i = 0.02$, where $N_b$ and $N_i$ are the total number of beam ions and that of thermal ions. The maximum amplitude increases with the beam velocity $v_b/v_{Ti}$ for both cases. It is interesting to note that the growth rate is negligibly small for $v_b < v_{Ti}$ and it starts to increase with $v_b$ as soon as $v_b$ becomes larger than $v_{Ti}$, regardless of the value of $N_b/N_i$. This phenomena can be explained in the followings.

We have a rough relation $v_d/v_{Ti} \sim \rho_{i0}/L$ for an MHD equilibrium, where $v_d$ is the average drift velocity. Let us suppose that the beam is injected in a narrow region near the field-null ($L \sim (r_{sp}-R)/5 < \rho_{i0}$). For a weak beam ($v_b < v_{Ti}$), the average width of current profile $L$ is given by $r_{sp} - R$ ($> \rho_{i0}$), i.e., $v_d/v_{Ti} \sim \rho_{i0}/L < 1$, where $r_{sp}$ and $R$ are the separatrix radius and the radius of the field-null, respectively. The DK mode is stabilized in the current profile with a weak beam of $v_b < v_{Ti}$ due to the ion magnetization effect ($\rho_{i0}/L < 1$). The average width decreases as the beam velocity or the beam current increases. We have the relations as $v_d/v_{Ti} \sim v_b/v_{Ti} \sim \rho_{i0}/L > 1$ for a strong beam ($v_b > v_{Ti}$). Thus, the strong beam of $v_b/v_{Ti} \gg 1$ destabilizes the DK instability because $\rho_{i0}/L \gg 1$.

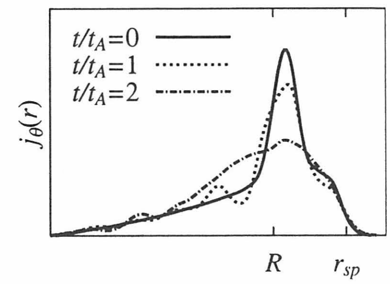


Figure 1: Radial profile of the averaged toroidal current density on the midplane at three different time periods.

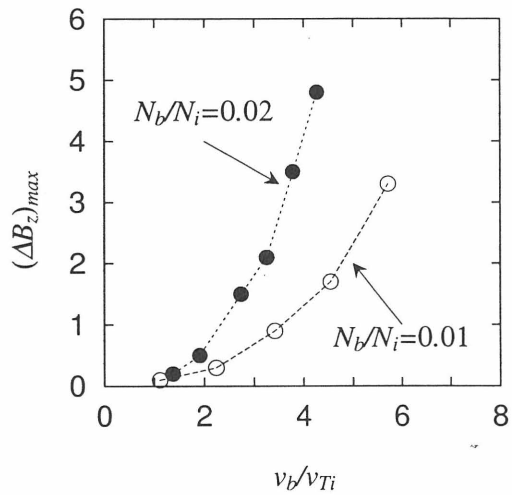


Figure 2: Dependence of the saturation levels of the drift kink mode on the beam velocity $v_b/v_{Ti}$ for two different values of $N_b/N_i$ : $N_b/N_i = 0.01$ (open circles) and $N_b/N_i = 0.02$ (closed circles).


References

1) R. Horiuchi, K. Nishimura, T.H. Watanabe and T. Sato, Nuclear Fusion **39**, 2083 (1999).

2) K. Nishimura, R. Horiuchi and T. Sato, Phys. Plasma **6**, 3459 (1999).