§6. Interaction Between Rotating Magnetic Islands with Error Fields

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Control of magnetic islands is an important issue for magnetically confined fusion plasmas. Magnetic islands rearrange pressure profiles, and the locking of magnetic island rotation affects the plasma flow profiles and occasionally triggers the disruptions in tokamaks. The locking of the magnetic island rotation is associated with the J × B torque due to the interaction between magnetic islands and error fields and/or resistive walls. In particular, the error field is caused by the misalignment of ambient magnetic coils or an set of external coils.

In the present study, the detailed mechanism of the locking of the magnetic island rotation by the error field is investigated numerically and analytically.

We consider tokamak plasmas with a large aspect ratio R_0/a, where R_0 and a are the major and the minor radii. A reduced set of Braginskii's two fluid equations is introduced, and the collisional drift-tearing mode is considered, where the $(2, 1)$ tearing mode is linearly unstable in the presence of the electron diamagnetic flow[1]. Error field is induced by imposing the finite edge boundary condition of the vector potential, and the magnitude of the error field is 5×10^{-4} times that of the ambient magnetic field.

Figure 1 shows the time evolution of the rotation frequency of the magnetic island, where the positive sign corresponds to the direction of the electron diamagnetic drift. Two cases are examined: a case without the error field and a case with the error field after $t = 10000$. In the latter case, the damping oscillation of magnetic island is observed, and the rotation frequency finally converges to zero, i.e. the rotation is locked by the error field.

Figure 2 shows the radial profiles of velocities of the diamagnetic flow, the $E \times B$ flow and the total of them after the locking of the magnetic island rotation. Two bars indicate radial positions of the inner and the outer separatrixes of the magnetic island. It is observed that the diamagnetic flow and the $E\times B$ flow cancel each other out inside the magnetic island. Since the diamagnetic flow is not strongly affected by the error field, it is found that the modification of the $E\times B$ flow profile is essential for the locking.

Based on the analysis of the nonlinear simulations, we derive a low dimensional model which describes the time evolution of the rotation frequency of magnetic islands such that

$$\frac{\partial}{\partial t}\Theta = \omega_r, \tag{1}$$

$$\frac{\partial}{\partial t}\omega_r = -C_M \sin\Theta + C_V\left(\bar{\omega}_r - \omega_r\right), \tag{2}$$

where Θ is the phase angle of the O-point, ω_r is the rotation frequency and $\bar{\omega}_r$ is the time averaged rotation frequency ($\bar{\omega}_r \to 0$ in the locking phase). C_M depends on the island width and the error field, and C_V is associated with the plasma viscosity and the island width. Eqs.(1)-(2) describes the pendulum-type damping oscillation. The time scale of the damping oscillation and the threshold of the locking in the nonlinear simulations are quantitatively explained by these formulae.

In future works, the detailed structure of the $E \times B$ flow in the locked state is investigated. Moreover, we examine the dynamics of magnetic islands due to the forced reconnection where the tearing mode is stable but the mode is destabilized by the error field. Such instability is commonly observed in tokamaks and helical systems.

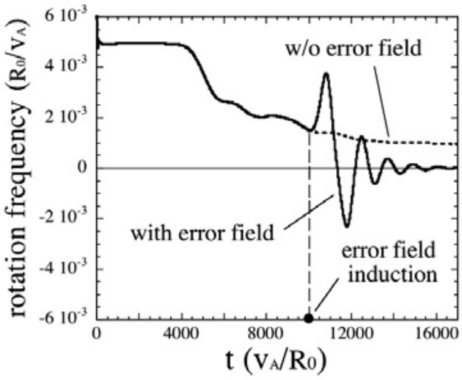

Fig. 1: Nonlinear time evolution of the rotation frequency of magnetic islands. v_A indicates the Alfvén velocity.

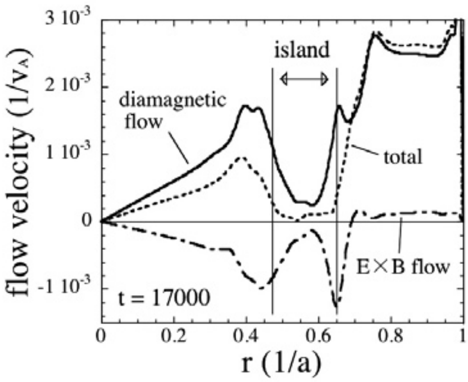

Fig. 2: Radial profiles of velocities of diamagnetic flow, $E \times B$ flow and their summation after the locking of the magnetic island rotation at $t = 17000$.

1) Nishimura, S., *et al.*, Phys. Plasmas 15 (2008) 092506.

2) Nishimura, S., *et al.*, Nucl. Fusion 50 (2010) 054007.