§5. Effect of Parallel Diffusion of Equilibrium Pressure on Interaction between Interchange Mode and Static Magnetic Island

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Direct interaction between a static magnetic island induced by an error magnetic field and a resitive interchange mode is numerically studied by utilizing a nonlinear simulation code NORM[1] based on the reduced MHD equations. We employ a straight LHD equilibrium with a large resistivity of $S = 10^4$ which is unstable for the resistive interchange mode. We analyze the interaction between the island and the mode both of which mode number is $(m,n) = (1,1)$. In our previous work[2], two independent solutions were found for a given error field. One is the case where the island width is increased due to the nonlinear saturation of the interchange mode and the other is the case decreased. The results depend on the sign of the initial perturbation of the interchange mode. In this study, we included the effect of the pressure diffusion parallel to the magnetic field only in the perturbation. Here we include the the parallel diffusion in the equilibrium pressure P_{eq} as well and analyse the effect on the change of the island width.

Figure 1 shows the island width in the initial state and in the satration state as a function of Ψ_b in the case with the parallel diffusion of P_{eq}. Here Ψ_b denotes the poloidal flux at the edge corresponding to the error field. The island width is always increased by the evolution of the interchange mode, unlike the case without the parallel diffusion of P_{eq}. Figure 2 shows an example of the island change between the initial and the saturation states.

The reason why only the solution of the increase of the width is obtained is attributed to the profile of the initial condition of the pressure. The parallel diffusion generates an inhomogeneous term P_b in the pressure equation, which is given by

$$P_b = -\kappa_{\parallel}(1 - \iota)\Psi_b \frac{dP_{eq}}{dr}, \qquad (1)$$

where $\kappa_{\parallel}$ and ι denote the parallel heat conductivity and the rotational transform. This term gives an initial perturbation of the pressure. As shown in Fig.3, P_b is positive for $r < r_s$, where r_s is the radial position of the resonant surface. On the other hand, in the case of $\Psi_b = 0$, we obtained the pressure in the saturation state has its peak value at $r = r_m$ with $r_m < r_s$ and the sign of the peak value is the same as that of the initial perturbation at $r = r_m$. We also obtained the sign of the poloidal magnetic flux at $r = r_s$ coincides with that of the pressure in the case. By applying this analogy to the finite Ψ_b case, we conclude that the positive value of $P_b(r = r_m)$ results in the positive value of the saturated pressure at $r = r_s$ as shown in Fig.3, and therefore, the saturated poloidal flux. Hence, the island widhth is increased by the saturation of the interchange mode because the width is proportional to the square root of the poloidal flux.

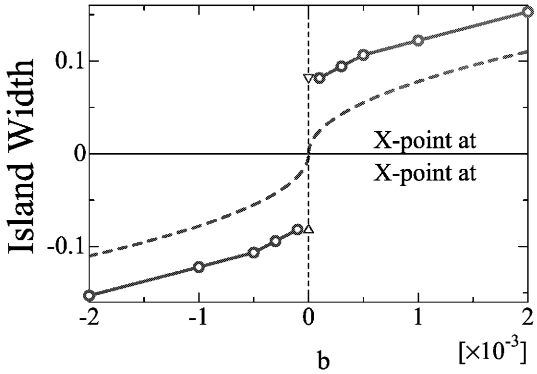

Fig.1 : Dependence of island width on Ψ_b in the initial (dashed line) and the saturation (△ and ○) states.

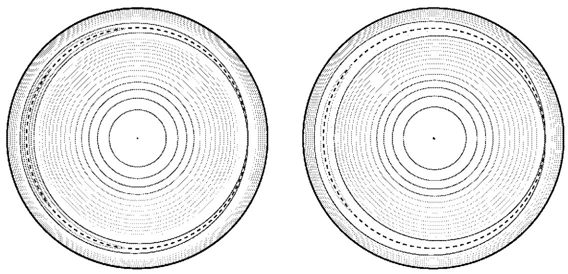

Fig.2 : Contours of helical magnetic flux for $\Psi_b = 2.0 \times 10^{-3}$ in the initial (left) and the saturation (right) states.

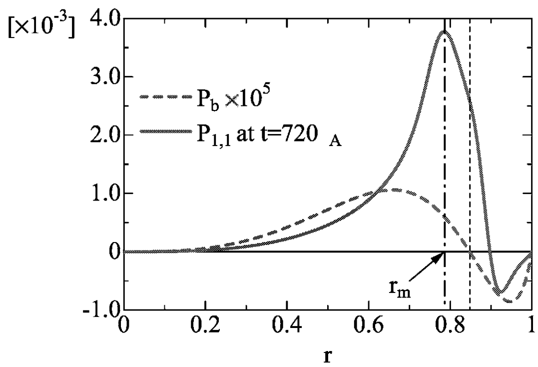

Fig.3 : Profiles of $(m,n) = (1,1)$ component of perturbed pressure and P_b. Vertical dashed line indicates the position of $r = r_s$.

1) Ichiguchi, K. et al., Nucl. Fusion **43**, 1101 (2003).
2) Saito, K. et al., Phys. Plasmas **17**, 062504 (2010).