§13. Stability of Externally Driven Magnetic Islands in a Rotating Helical Plasma

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In the Large Helical Device(LHD), resonant magnetic perturbation(RMP) by external current coils or error fields is basic for the divertor configuration and the confinement improvement. RMP produces magnetic islands in the vacuum magnetic field but plasma response affects stability magnetic islands, where spontaneous shrink of islands is called self-healing[1]. In tokamaks, it is well known that forced magnetic reconnection by RMP is suppressed by a screening effect of plasma flows. Since plasma flows are generated by neoclassical viscosity due to rippled magnetic field in helical plasmas, the screening mechanism is also expected as that in tokamak plasmas. In fact, the self-healing is reproduced by theoretical models taking into account neoclassical flows[2]. Historically, it is know that the curvature driven tearing mode is crucial for helical plasmas in the context of three-dimensional magnetohydrohynamic equilibrium. Reduced fluid simulations in helical plasmas have been also developed, and it is found that RMP driven islands are amplified by the resistive interchange mode[3]. In this work, we simulate coexistence of RMP driven islands and the resistive interchange mode using reduced fluid equations including RMP, neoclassical viscosity and the curvature effect.

Physical assumption made in our model, which is used for tokamak plasmas, is described in a separated article[4]. RMP is introduced through the boundary condition of the poloidal magnetic flux perturbation. We consider a helical plasma with the average minor radius a and the major radius R_0. To model a rotating helical plasma, the average normal magnetic field line curvature and the neoclassical viscosity $\nu^{\rm nc}(V_0 - v_\theta)$ are newly taken into account, where $\nu^{\rm nc}$ is the ion neoclassical damping rate, V_0 is the equilibrium ion neoclassical flow velocity and v_θ is the poloidal flow velocity. In the following simulations, we set $\beta = 0.01$ and $\epsilon = a/R_0 = 0.2$, where β is the ratio between the total plasma pressure at the plasma center and the magnetic pressure $B_0^2/4\pi$ and B_0 is the toroidal magnetic field.

Figure 1 shows neoclassical damping rate $\nu^{\rm nc}$ dependence of the saturated magnetic island width in cases (a) with and (b) without average curvature effects. In Fig.1, w is the magnetic island width, a is the average minor radius and $\tau_{\rm A} = R_0/v_{\rm A}$, where $v_{\rm A}$ is the Alfven velocity at the plasma center. The simulations are started from the magnetic field in the vacuum field limit with RMP, i.e. the initial magnetic island width is the vacuum island width. In Figs.1(a) and (b), large locked islands are produced in the small $\nu^{\rm nc}$ regime, while, islands are healed in the large $\nu^{\rm nc}$ regime. In Fig.1(a), small non-rotating islands, which are still larger than the linear layer width, are observed. In Fig.1(b), the error bars in the high $\nu^{\rm nc}$ regime are due to the island rotation. It is observed that the self-healing threshold is shifted by the curvature effect.

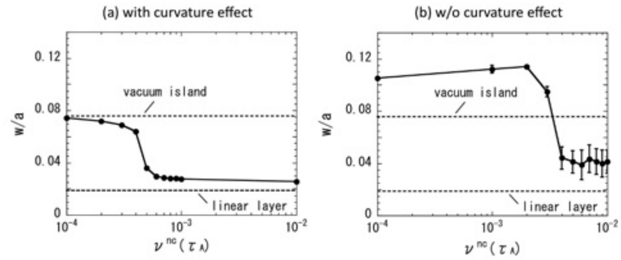

Fig. 1: Neoclassical damping rate dependence on the saturated magnetic island width in cases (a) with and (b) without the curvature effect. The vacuum island width and the visco-resistive linear layer width are shown.

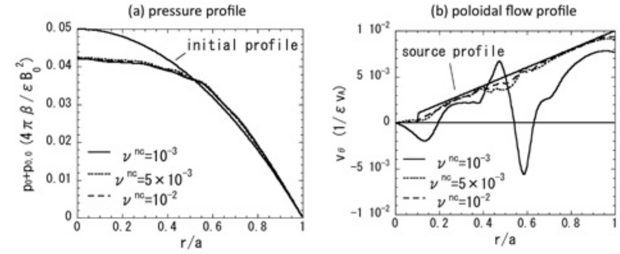

Fig. 2: Radial profile of (a) pressure and (b) poloidal flows in nonlinear saturation states of the fixed RMP simulations with curvature effects.

Figure 2 shows radial profiles of the (a) pressure and (b) poloidal flows in nonlinear saturation states of the fixed RMP simulations with curvature effects, where the rational surface is located at $r/a = 0.54$. Three cases with $\nu^{\rm nc} = 10^{-3}$, 5×10^{-3} and 10^{-2} are plotted. In Fig.2(a), collapse of the pressure is due to the convective transport by the resistive interchange mode and magnetic islands hardly affect the pressure profile. In Fig.2(b), poloidal flows are damped at the rational surface when the large islands are excited. In other words, the self-healing of islands occurs when the locking of flows is not maintained.

1) Narushima, Y. et al. : Nucl. Fusion **51** (2011) 083030.

2) Nishimura, S. et al. : Plasma Fusion Res. **5** (2010) 040.

3) Saito, K. et al. : Phys. Plasmas **17** (2010) 062504.

4) Nishimura, S. and Yagi, M. : Plasma Fusion. Res. **6** (2011) 2403119.