§2. Rotation Effects on LHD Plasma Stability

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The rotation effects on the magnetohydrodynamics stability against the interchange modes in the LHD plasmas are studied with the numerical simulation [1]. As the numerical procedure, we employ a static equilibrium and incorporate a model shear flow as the rotation in the initial perturbation of the stability calculation. Three-dimensional numerical codes of HINT [2] and MIPS [3] are utilized for the equilibrium and the stability calculations, respectively. To make the effects on the stability remarkable, we employ a strongly unstable LHD configuration.

In the equilibrium calculation, we employ the pressure profile of $P_{eq} = P_0(1-\rho^2)(1-\rho^8)$ and the axis beta of 4.4 %, where ρ denotes the square root of the normalized toroidal magnetic flux. In this equilibrium, the $\iota = 1$ surface exists in the plasma column, where ι is rotational transform. The Mercier stability is unfavorable at the $\iota = 1$ surface. As for the specification of the rotation, we implement only the poloidal flow, which is assumed to be a function of the flux surface, $V_\theta(\rho)$. The profile of V_θ is chosen so as to be similar to that observed in LHD experiments, which shows a substantial shear flow at the $\iota = 1$ surface. Hereafter, we refer the flow by the maximum value in the profile of V_θ/V_A, where V_A denotes the Alfvén velocity.

In the case of no flow, $V_\theta/V_A = 0$, an unstable mode grows linearly and is saturated nonlinearly. As shown in Fig.1 (a), the $(m, n) = (4, 4)$ interchange mode is dominant. Substantial pressure collapse are seen and the field lines are also made stochastic. Here, m and n are the poloidal and toroidal mode numbers, respectively. In the case of $V_\theta/V_A = 10^{-3}$, the initial kinetic energy of the flow is much less than E_{ksat}, where E_{ksat} denotes the saturation level of the kinetic energy in the no flow case. The kinetic energy has almost the same value in the saturation phase. Therefore, similar pressure collapse and field line stochasticity to those in the no flow case are obtained.

In the case of $V_\theta/V_A = 10^{-2}$, the initial kinetic energy is comparable to E_{ksat}. As shown in Fig.1 (b), the deformation of the total pressure and the stochastic region of the field line are small compared to those in the no flow case, respectively. Besides, the dominant mode numbers are reduced to $(m, n) = (2, 2)$, as is often seen in the stabilization due to the dissipation such as viscosity and heat conductivity. In the case of $V_\theta/V_A = 10^{-1}$, the initial kinetic energy is about two order larger than E_{ksat}. The stabilizing contribution is further enhanced. No change is seen in the pressure profile and the flux surfaces in the saturation phase as shown in Fig.1 (c). That is, the interchange mode is suppressed.

As a summary, the poloidal shear flow can stabilize interchange modes in LHD when the kinetic energy is sufficiently larger than the saturation level of the mode in the no flow case. Therefore, the plasma rotation is a candidate of the key physics for the stabilization in LHD. In order to make more precise validation, the upgrade of the model flow and the static equilibrium to ExB and diamagnetic rotations and stationary states consistent with the rotations is addressed, respectively.

(a)

(b)

(c)

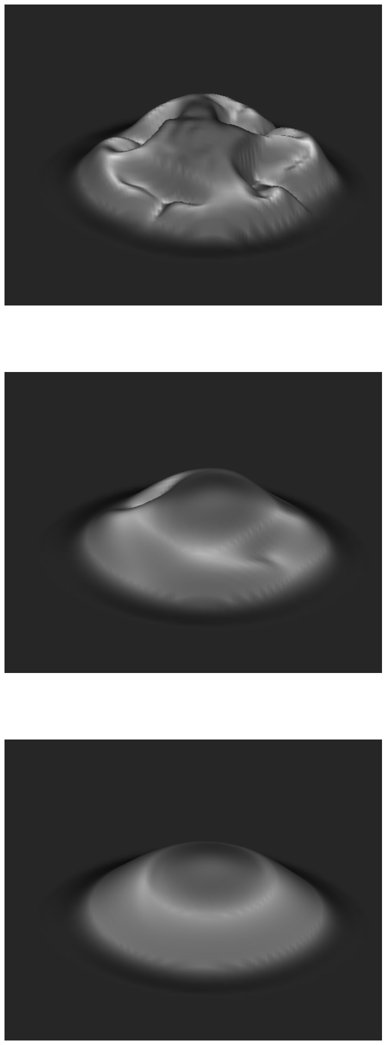

Fig.1. Bird's eye view of total pressure at the same time in the nonlinear saturation phase for $V_\theta/V_A =$ (a) 0, (b) 10^{-2} and (c) 10^{-1}.

[1] K. Ichiguchi, et al., Plasma and Fusion Research, **11** (2016), 2403035.
[2] Y. Suzuki, et al, Nucl. Fusion **46** (2006) L19.
[3] Y. Todo, et al, Plasma and Fusion Res. **5** (2010) S2062.