Numerical Study of Non-Resonant Pressure Driven Mode in Heliotron Plasma

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In the LHD configuration with the vacuum magnetic axis located at 3.6m, sawtooth-like oscillations were observed in the soft X-ray camera system in fairly high density plasmas produced by pellet injection[1]. The mode was localized around the magnetic axis and had $m = 3$ mode structure. In the vacuum configuration, the rotational transform has the value of 0.35 at the axis and increases monotonously in the radial direction. Therefore, the resonant surface for $(m, n) = (3, 1)$ mode does not exist in this profile. The resonant surfaces for $(m, n) = (3,2)$ and (3,3) exist, however, they are apart from the axis. Thus, the possibility of a non-resonant mode in such configuration is studied numerically. In this study, we utilize the VMEC code[2] for the 3D equilibrium and the NORM code[3] for the linear stability and the nonlinear dynamics.
We use the pressure profile expressed by

$$P(\rho) = P_0 \begin{cases} (1 - a\rho^2) & for \quad 0 \le \rho \le \rho_0 \\ b(1-\rho)(1-\rho^8) & for \quad \rho_0 \le \rho \le 1 \end{cases} \tag{1}$$

where ρ denotes a square-root of the normalized toroidal flux. The factors of a and b are determined so that the value and the first derivative of P should be continuous at $\rho = \rho_0$. Here we employ $\rho_0 = 0.1$. We obtain a non-resonant $(m, n) = (3, 1)$ mode in the region of $0.3\% \le \langle\beta\rangle \le 0.8\%$ for the pressure profile. As we employ the no net current condition for the equilibrium calculation, the rotational transform around the axis approaches to 1/3 in this beta region. Therefore, it is necessary for the destabilization of the non-resonant mode with (m, n) that the rotational transform at the axis is close to n/m.
We examine the nonlinear dynamics of the non-resonant mode by utilizing a multi-scale numerical scheme[4]. We increase the beta value by adding a small pressure increment with the profile of eq.(1). The $(m, n) = (3, 1)$ mode dominantly grows when the beta value enters the linearly unstable region. The reduction of the axis beta is obtained in the growth of the mode, which may correspond to the sawtooth-like oscillation in the experiment.
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[1] S. Ohdachi et al., Proc. Fusion Energy Conf. 2006, EX/P8-15.
[2] S.P. Hirshman, et al., Comput. Phys. Commun. **43**, 143-155 (1986).
[3] K. Ichiguchi, et al., Nucl. Fusion **43**, 1101-1109 (2003).
[4] K. Ichiguchi, et al., Plasma Fus. Res. **3**, S1033 (2008).