6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Nonlinear transition of pressure driven modes in heliotron configuration

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In the LHD experiments, partial collapse phenomena are observed when the net toroidal current is driven by the neutral beam injection so that the rotational transform $\iota/2\pi$ is increased [1-3]. These collapses are always caused by the (m,n)=(1,1) mode, where m and n are the poloidal and the toroidal mode numbers, respectively. This mode is considered to be a pressure driven mode because the equilibria are strongly Mercier unstable. However, according to the theory of pressure driven modes, the linear growth rate is larger for higher mode numbers. Therefore, it has been necessary to explain why the partial collapses in LHD are caused by the mode with the lowest mode numbers.

In order to consider the reason, we carry out three-dimensional nonlinear MHD simulations for the plasma with the net toroidal current in the magnetic configuration where the collapse is observed, first [4]. In the simulations, we utilize the HINT code [5] for the three-dimensional equilibrium calculation. As for the analysis of the linear stability and the nonlinear dynamics of the perturbation, we utilize the MIPS code [6]. We mainly focus on the case where the rotational transform is close to unity and the profile is flat in the core region due to the net toroidal current as shown in Fig.1 (a). In this case, the interchange mode resonant at $\iota/2\pi=1$ becomes unstable in the linear phase. The mode number of the dominant component is higher than (1,1). On the other hand, in the nonlinear phase, the (1,1) component can appear and become dominant as shown in Fig.1 (a). This mode is localized in the core region where the shear is weak, not around the $\iota/2\pi=1$ surface. The profile of the total pressure shows the m=1 deformation as shown in Fig.1 (b). This means that a nonlinear transition from the interchange mode to a non-resonant mode occurs. Since it is observed that the partial collapses are caused by the (1,1) mode in the LHD experiments with the net toroidal current, this transition is considered to be a candidate to explain the observation.

In addition, we have also found similar nonlinear transition in the simulation for the plasmas without net toroidal current. The transition is found in the magnetic configuration where the aspect ratio of the plasma is tighter than that in the above configuration. In this case, the rotational transform is larger in the comparison with no net toroidal current, although the value in the core region is not as close to unity as the above equilibrium. The common feature of these nonlinear transition is that the (m,n)=(1,1) component seems to be generated by the nonlinear convolution of the (m,n) and the (m+1,n+1) components.

References

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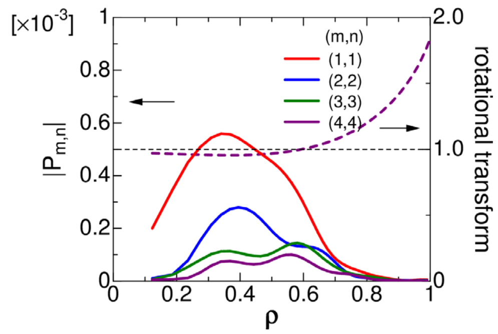
(a)



(b)

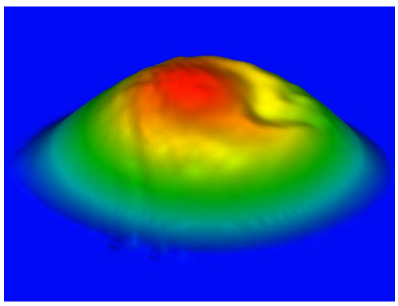


Figure 1 :
(a) Profiles of the largest four Fourier components of the perturbed pressure absolute value, (b) bird's eye view of the total pressure in the nonlinear saturation phase of the pressure driven mode for I/B=29.6kA/T and β_0=1.4%. Thick dashed line shows the profile of the equilibrium rotational transform in (a).