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Numerical simulation of interaction between global flow and interchange modes in heliotron plasmas

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Concerning with the magnetohydrodynamic (MHD) stability in heliotron plasmas, we study the nonlinear interaction between the global flow and the interchange modes using three-dimensional (3D) numerical simulations. In the Large Helical Device (LHD) experiments, partial collapses of the electron temperature profile due to the interchange mode are sometimes observed. In the collapses, the onset of the mode growth and the mode rotation stop are synchronized [1]. The mode rotation is dominated by the background plasma flow [2]. This phenomenon suggests the interaction between the background global flow and the interchange mode, particularly the stabilizing contribution of the flow on the mode. On the other hand, there are several previous theoretical works on the interaction between the interchange modes and the global flow. Watanabe et al.[3] and Chu[4] studied the effects on the ideal interchange modes. They found a destabilizing contribution due to the Kelvin-Helmholtz instability in the local stability criterions. Sugama et al.[5] studied the effects on the resistive g-modes in the electro-static framework. They found a stability window appears between the interchange and Kelvin-Helmholtz instabilities when the amount of the flow velocity is increased. Carreras et al.[6] also found such stability window.

Thus, in the present study, we analyze the nonlinear evolution of the interchange mode with keeping the flow. For this purpose, we have developed the numerical scheme to calculate the flow consistent with the experimental data at first. In LHD, one-dimensional radial profiles of the poloidal and the toroidal components of the flow are observed [7]. The scheme can provide the 3D profile corresponding to the data in the entire plasma region under the assumption of the steady flow [8]. A static equilibrium calculated with the HINT code [9] is utilized as the initial state in the nonlinear dynamics simulation with the MIPS code [10]. The 3D flow data is incorporated in the initial perturbation. The viscosity damping of the flow is avoided by the implementation of the compensation term in the momentum equation.

The results of the simulation show that a sufficient large flow has a stabilizing contribution to the nonlinear evolution of the interchange mode. On the other hand, in the case of quite large flow, the Kelvin-Helmholtz instability appears and induces a partial collapse of the pressure profile.

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