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Three-Dimensional MHD Analysis of Heliotron Plasma with RMP

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In the recent study of magnetically confined fusion plasmas, resonant magnetic perturbations (RMPs) are studied from the viewpoint of the magnetohydrodynamics (MHD) stability against pressure driven modes, because RMPs can locally change the pressure gradient. Particularly, in heliotrons, since pressure driven modes are the most dangerous, the change of the pressure gradient can directly influence the global stability. Here, the interaction between pressure driven modes and magnetic islands generated by an RMP is numerically analyzed in a Large Helical Device (LHD) configuration with a high aspect ratio and magnetic hill. For the MHD analysis of the RMP effects, an equilibrium with a pressure profile consistent with the disturbed magnetic surfaces is necessary. To obtain such an equilibrium, we utilize the HINT2 code, which finds a three-dimensional (3D) equilibrium without any assumption of the existence of nested surfaces. A horizontally uniform RMP is applied and an m=1/n=1 magnetic island is generated in the equilibrium. The pressure profile is deformed so that the gradient is smaller at the O-point than at the X-point. Next, the plasma dynamics is examined with the MIPS code, which solves the full 3D MHD equations by following the time evolution. In this LHD configuration, a typical interchange mode is the most unstable instability in the case without the RMP. On the other hand, in the case with the RMP, because of the poloidal asymmetry of the equilibrium pressure a ballooning type mode is the most unstable, with the mode structure localized around the X-point. The mode can utilize the driving force most effectively by being localized around the steepest pressure gradient point. In the nonlinear evolution of the mode, the pressure starts to collapse around the X-point, and then, the collapse spreads to the core region. Therefore, the phase of the mode structure in the poloidal and the toroidal directions is fixed to that of the island. Such fixed phase is observed in the LHD experiments with a natural error field that works as an RMP. Further analysis for a wide range of parameters will allow us to understand further the RMP effects on the pressure driven modes.

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