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Three-dimensional numerical analysis of interaction between plasma rotation and interchange modes

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Effects of the poloidal shear rotation on the magnetohydrodynamic (MHD) stability of interchange modes in a Large Helical Device (LHD) configuration are numerically studied. This simulation is the first three-dimensional (3D) full-MHD nonlinear analysis for heliotron plasmas including the flow.
In LHD, the highest average beta value of 5.1% is successfully obtained in the configuration where the plasma is predicted to be unstable with respect to the Mercier criterion. Thus, some stabilizing effects work on the plasma and it is crucial to identify the key physics of this stabilization for not only the understanding of the LHD plasmas but also the accurate design of the helical DEMO. Recently, it is observed in the experiments that the magnetic perturbation grows rapidly just after the mode rotation stops and causes a partial collapse of the electron temperature. This phenomenon indicates that the plasma rotation may suppress the growth of the mode.
Thus, we numerically study the rotation effects on the MHD stability against the interchange modes in the LHD plasmas. 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. The 3D numerical codes of HINT and MIPS are utilized for the equilibrium and the stability calculations, respectively. We apply this method to an LHD equilibrium that is unstable for the interchange mode. In the no flow case, the pressure profile collapses and the magnetic field lines becomes stochastic in the nonlinear saturation phase. When a flow of which the kinetic energy is much larger than the saturation level in the no flow case is applied initially, such pressure collapse and field line stochasticity are not seen.
Hence, this simulation result shows that a large initially-applied poloidal flow can suppress the interchange modes. In this simulation, the flow needed for the suppression is much larger than the flow observed in LHD experiments. However, we expect that we can reduce the needed flow when we take it into account that the nonlinear relaxation of the mode continues in the beta ramp-up phase. Therefore, the plasma rotation is considered as one of the candidates of the stabilization mechanism in LHD.

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Primary author: Prof. ICHIGUCHI, Katsuji (National Institute for Fusion Science)

Co-authors: Dr CARRERAS, Benjamin (Universidad Carlos III, Spain); Dr SATO, Masahiko (National Institute for Fusion Science); Prof. SAKAKIBARA, Satoru (National Institute for Fusion Science); Dr OHDACHI, Satoshi (National Institute for Fusion Science); Dr NICOLAS, Timothee (JpNIFS); Dr SUZUKI, Yasuhiro (National Institute for Fusion Science); Dr TODO, Yasushi (National Institute for Fusion Science); Dr NARUSHIMA, Yoshiro (National Institute for Fusion Science); Dr TAKEMURA, Yuki (JpNIFS)

Presenter: Prof. ICHIGUCHI, Katsuji (National Institute for Fusion Science)

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