DNS Studies of Nonlinear Evolution of MHD Instability in LHD

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By aiming at clarifying basic plasma behaviors in nonlinear evolution of MHD instability in the large helical device[1], direct numerical simulations of fully three-dimensional, compressible and nonlinear magnetohydrodynamic (MHD) equations[2] are carried out. An initial equilibrium is chosen, which has a peaked pressure profile with the beta at the magnetic axis being $\beta_0 = 3.7\%$ in the vacuum configuration with the magnetic axis position being $R = 3.6$m. Special attentions are paid to such effects as the flow parallel to the magnetic field lines and compressibility which are often neglected in a simpler model such as the reduced MHD models.

In the simulations, the linear growth of the interchange modes and their nonlinear saturations are observed. Fourier mode analysis in the Boozer coordinates reveals that velocity profiles obtained by the simulations shares typical characteristics with the linear ideal eigenfunctions, although relatively large viscosity in the simulation brings about smoothening of the profiles. It is also found by a simple analysis about the kinetic energy budget that the compressibility considerably reduces the linear growth rates of the unstable modes. The linear growth provides the parallel flows as strong as the perpendicular flows. In the nonlinear saturation process, a qualitative difference is found in the behaviors of the parallel and perpendicular flows. While the parallel flow has a long life-time compared to the perpendicular flows, a plasma finally approaches to a near-equilibrium state with finite parallel flow.

Although the parameter range of our simulations are far from the real experiments, the numerical results suggest that impacts of the linear instability on the confinement are weakened through the parallel flow excitations, compressibility, and nonlinear couplings, especially compared to the traditional reduced-type simulations. Our numerical results highlight important roles of the parallel flow and compressibility in examining the lienar and nonlinear growth of the MHD fluid in the helical system.

References

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