§2. MHD Stability Analysis for High Beta LHD Plasmas

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As the beta value increases in LHD plasmas, the Shafranov shift becomes large and the magnetic well is formed in the core region and the Mercier unstable region shifts form the core region to the peripheral region. Thus, the pressure driven MHD instabilities are theoretically unstable in the peripheral region for high beta LHD plasmas. In this study, the linear properties and nonlinear phenomena of the pressure driven modes for high beta LHD plasmas have been investigated by MHD simulation[1]. The MHD simulation is carried out by using the MIPS code (MHD Infrastructure for Plasma Simulation) [2], which solves the full MHD equations in the cylindrical coordinates (r, φ, z). The original MIPS code uses a fourth-order finite difference method for the spatial derivatives and the fourth-order Runge-Kutta method for the time integration. For the high beta LHD plasmas, since the pressure driven modes becomes unstable in the periphery region, the perturbed plasma flow grows near the plasma boundary. Then, the numerical oscillation appears near the plasma boundary when the dissipation coefficients are not enough large. In order to avoid the numerical oscillation, the Kawamura-Kuwabara method (3rd order upwind scheme)[3] is used for the convection terms in this study. This allows us to carry out nonlinear simulation with small dissipation coefficients.

MHD stability analyses have been performed for three MHD equilibria with β_0 =7.4%, 9.4% and 11% where β_0 is a central beta value. The MHD equilibira are constructed by HINT2 code. The rotational transform is larger than 0.5 everywhere and the magnetic shear is weak in the core region. The normalized viscosity and thermal diffusion coefficient are set to be 10^{-7}. The magnetic Reynolds number S is chosen from 10^5 to 10^7. The density is assumed to be uniform for simplicity. The number of the grid points is (256, 640, 256). For these MHD equilibria, the ballooning modes are destabilized in the peripheral region. Figure 1 shows the dependence of the linear growth rate on the magnetic Reynolds number. Since the linear growth rate decreases as the magnetic Reynolds number increases, the unstable modes are considered to be resistive ballooning modes. For β_0 =7.4%, 9.4%, the linear growth rate does not depends on the beta value. However, the dependence of the linear growth rate for β_0 =11% on the magnetic Reynolds number is stronger than for β_0 =7.4%, 9.4%. The linear growth rate for β_0 =11% becomes smaller than for β_0 =7.4%, 9.4% when the magnetic Reynolds number is large. Although the linear mode is destabilized in the peripheral region, the low modes are nonlinearly destabilized in the core region and the central pressure decreases. Figure 2 shows the dependence of the saturated central beta value on the initial central beta value. When the initial beta value is 7.4% or 9.4%, the saturated beta value is about 6%. However, when the initial beta value is 11%, the saturated beta value is larger than 8%. Thus, for high beta LHD plasmas, as the beta value increases, the linear growth rate and the saturation level of the pressure driven modes are reduced.

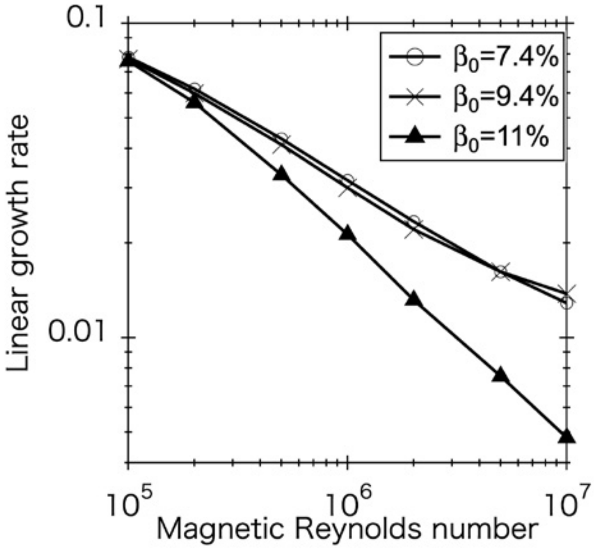

Fig. 1. Dependence of the linear growth rate on the magnetic Reynolds number for three MHD equilibria with β_0 =7.4%, 9.4% and 11%.

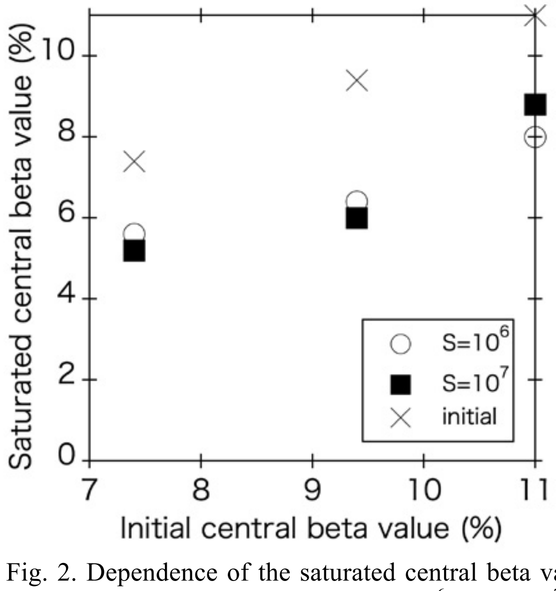

Fig. 2. Dependence of the saturated central beta value on the initial central beta value for S=10^6 and S=10^7.

1) Sato, M. et al.: Proc. of 24th IAEA Fusion Energy Conf. (San Diego, USA, 2012) IAEA-CN-197/TH/P3-25.
2) Todo, Y. et al.: Plasma Fusion Res. **5** (2010) S2062.
3) Kawamura, T. and Kuwabara, K.: AIAA Paper **84** (1994) 0340.