# §2. MHD Simulation for High Beta LHD Plasmas with Free-boundary Condition

Sato, M., Nakajima, N., Watanabe, K., Todo, Y., Suzuki, Y.

In the Large Helical Device (LHD) experiments, stable high beta plasmas with about 5% of the volume averaged beta value have been obtained routinely. For such high beta LHD plasmas, the pressure driven modes are theoretically unstable in the peripheral region. In order to understand why high beta plasmas are stably obtained in LHD, full MHD simulations including the chaotic magnetic field region have been performed by using MIPS (MHD Infrastructure for Plasma Simulation) [2] code, which solves the full MHD equations in the cylindrical coordinates (r, φ, z). The MIPS code uses a fourth-order finite difference method for the spatial derivatives and the fourth-order Runge-Kutta method for the time integration. Our previous study found that there is a tendency that modes are suppressed as the beta value and/or magnetic Reynolds number increase, which is consistent with a result that high beta plasmas enter the second stable region of the ideal ballooning modes as beta increases[3]. In Ref.[1], the fix-boundary condition is used such that the velocity set to be zero at the plasma boundary of the MHD equilibrium. For high beta LHD plasmas, since the MHD modes are unstable in the peripheral region, the stability may be affected by the boundary condition.

In this study, in order to clarify the influence of the boundary condition on the MHD instability in the high beta LHD plasmas, the MIPS code is improved to treat free boundary problem using the pseudo-vacuum plasma model. Here the vacuum region is replaced with low density plasma where the ratio of the density in the pseudo-vacuum ($\rho_v$) to the density at the center ($\rho_0$) is set to be $\rho_v/\rho_0$=0.1. For simplicity, the resistivity is assumed to be uniform. In Fig.1, the shape of the simulation boundary is shown by black line in poloidal sections. The plasma can expand beyond the plasma boundary of the MHD equilibrium. Fig.2 shows the dependence of the linear growth rate on toroidal mode number. Here the central beta value is assumed to be 9.4%. When the fix boundary condition is used, the effect of the density profile on the linear growth rate is small. However, the linear growth rate obtained by the free-boundary condition is about twice as large as one obtained by the fixed-boundary condition. The position of the maximum amplitude of the eigen-mode structure shifts outward when the free-boundary condition is used as shown in Fig.3, where $\rho$ =1 corresponds to the last closed flux surface. Therefore, the free-boundary condition is necessary for the linear MHD analysis of high beta LHD plasmas.

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) Nakajima, N. et al.: Nucl. Fusion **46** (2006) 177.

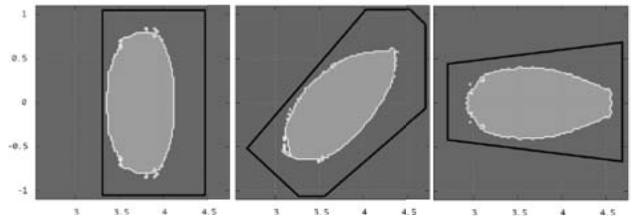

Fig.1. The shape of the simulation boundary in poloidal sections. The amplitude of perturbations are set to be zero at the boundary displayed by black line.

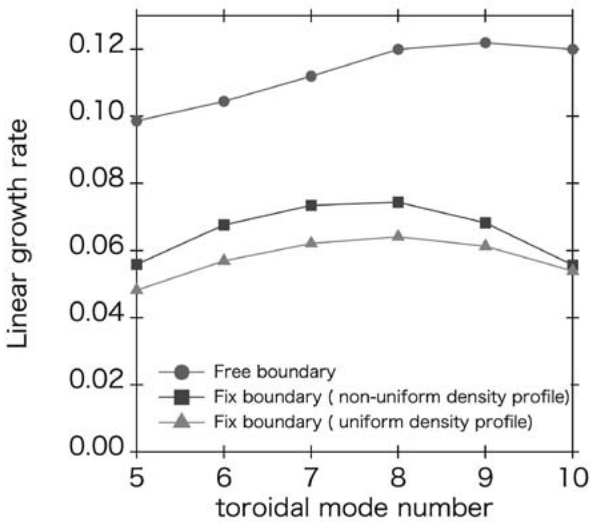


Fig.2. Dependence of the linear growth rate on the toroidal mode number.

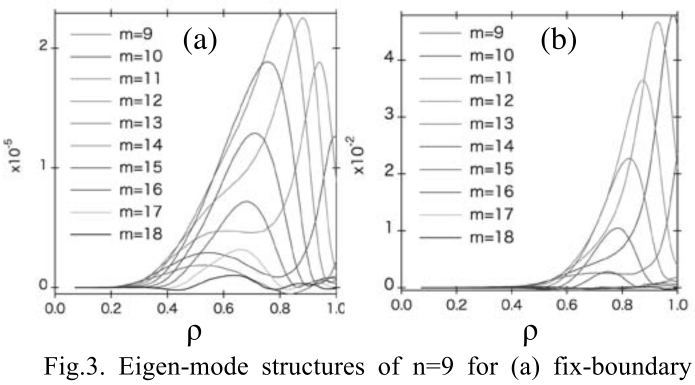


Fig.3. Eigen-mode structures of n=9 for (a) fix-boundary condition and (b) free-boundary condition.