§4. Multi-Scale MHD Simulation for LHD Plasma with Fixed Pressure Increment Profile

Ichiguchi, K., Carreras, B.A. (BACV Sol.)

In the LHD experiments, good confinement of the plasma has been observed in the region where linear ideal interchange modes were predicted to be unstable. In order to investigate the stabilizing mechanism, we developed the NORM code based on the nonllinear reduced MHD equations. In this study, it is crucial to follow the change of the pressure profile in the increase of the beta value. For this purpose, we develop a multi-scale simulation scheme with the NORM code. In this scheme, we take into account the equilibrium change due to the beta increase by calculating the equilibrium quantities and the nonlinear dynamics of the perturbations iteratively. We apply the multi-scale scheme to the LHD plasma with the vacuum magnetic axis located at $R_{ax} = 3.6m$.

In this scheme, the equilibrium pressure profile at $i+1$-th step is given by

$$P_{eq}^{i+1} = \langle P \rangle^i + \Delta P, \quad (1)$$

where $\langle P \rangle^i$ and ΔP denote the average pressure profile given by the nonlinear dynamics at i-th step and the increment of the pressure for $i+1$-th step, respectively. In the previous study, we assumed a pressure increment with a profile similar to $\langle P \rangle^i$, which is given by

$$\Delta P = \frac{\beta^{i+1} - \beta^i}{\beta^i} \langle P \rangle^i, \quad (2)$$

where β^i is the i-th β value. On the other hand, the heating profile in experiments is usually fixed during the increase of beta. To treat this situation, we consider a fixed profile for ΔP. Here we assume a profile of square of parabola given by

$$\Delta P = P_{add}(1-\rho^2)^2. \quad (3)$$

We start the multi-scale simulation from an initial pressure profile of $P = P_0(1-\rho^2)(1-\rho^8)$ with the average beta value of 0.225%. Figure 1 shows the time evolution of the average pressure profile for the fixed increment given by (3). The beta value is increased as time and the profile is locally changed by the nonlinear saturation of the interchange mode. The final pressure profile at $t = 60000\tau_A$ is plotted by the solid line. The average beta value at this time is $\beta = 0.498\%$. The pressure profile at the same time for the similar pressure increment given by (2) is also plotted for comparison. The pressure gradient near the magnetic axis for the fixed pressure increment is larger than that for the similar pressure increment. This is attributed to the fact that the pressure profile is almost maintained in the similar increment case once the profile becomes flat. On the contrary, the pressure gradient is continuously updated in the fixed increament case. Therefore, even once the pressure profile becomes locally flat, the gradient is increased until an instability occurs again.

This situation is reflected in the Mercier stability. The Mercier stability is improved around the resonant surfaces in both cases of the similar and the fixed increment cases as shown in Fig.2. The values of D_I is almost in the same level in the case of the fixed increment case, while the values at the resonant surface near the axis are much larger than those at other region in the similar increment case. Thus, in the fixed increment case, the pressure profile is self-organized so that a marginally stable profile should be generated.

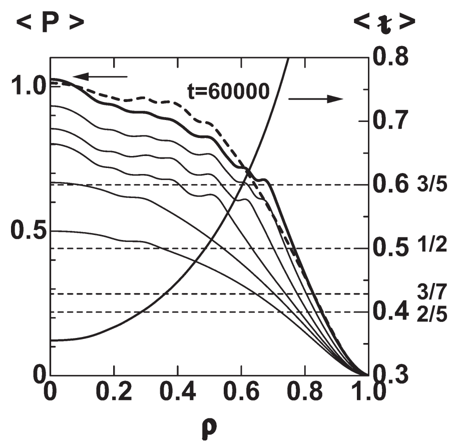

Fig.1 Time evolution of pressure profile.

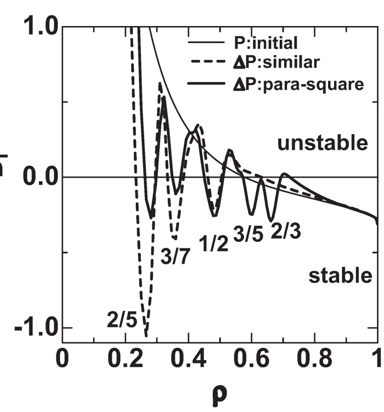

Fig.2 Mercier stability at $\beta = 0.498\%$.