§3. Study of Resistivity Effect on MHD Stability Beta Limit in LHD Using TASK-3D

Sato, M., Watanabe, K.Y., Nakamura, Y. (Kyoto Univ.), Fukuyama, A. (Kyoto Univ.), Murakami, S. (Kyoto Univ.), Yokoyama, M., Funaba, H., Sakakibara, S., Ohdachi, S., Yamada, H., Nakajima, N.

The MHD Stability beta limit in the Large Helical Device (LHD) has been analyzed using a hierarchy-integrated simulation code TASK3D[1] in order to explore the capability of the LHD configuration. For the analysis of the MHD stability beta limit, the MHD equilibrium module VMEC, the transport module TR and the linear MHD stability module MSSH are used. The numerical model for the effect of the MHD instabilities is introduced such that the pressure profile is flattened around the rational surface due to the MHD instabilities. The width of the flattening of the pressure gradient is determined form the width of the eigenmode structure of the MHD instabilities. It is also assumed that there is an upper limit of the poloidal mode number of the MHD instabilities; m_c which directly affect the pressure gradient. Recent experimental results suggest that eigenmodes of the MHD instabilities with poloidal mode number of $m \leqq 4$ dynamically affect the pressure profile. In our analysis, $m_c=4$ is used as the standard mode of the calculation of the achievable beta value. In the previous study[2,3], ideal interchange modes, which are most important instabilities in helical plasmas, were considered to give the MHD stability beta limit. It has been found that the achievable volume averaged beta value is expected to be beyond about 6% for $1.5 < \sigma < 1.6$, where σ is the peaking factor of the pressure profile. In this study, the linear MHD stability module MSSH has been extended to analyze resistive modes and the effect of the resistive interchange modes on MHD stability beta limit is investigated.

In this study, the 3D MHD equilibrium module VMEC, the 1D diffusive transport module TR, and the linear MHD stability module MSSH are used. The numerical scheme is as follows. First, a pressure profile is given and the equilibrium quantities are calculated by the VEMC module. Next, the linear resistive MHD stability is evaluated by the extended MSSH module for a helical plasma in the cylindrical limit. In the MSSH module, the averaged magnetic curvature term is evaluated by using the Mercier parameter obtained from the VMEC module, where the Suydam criterion is consistent with the Mercier criterion. The eigenmode structures obtained from the MSSH are used to evaluate the enhanced transport coefficient due to MHD instabilities in the transport module TR. In the TR module, the time evolution of the electron temperature is calculated. The ion temperature, ion density and electron density are fixed in this simulation. When the interchange mode becomes unstable, the effect of the MHD instability reflects on the transport coefficient by changing the transport coefficient to a larger value in order to flatten the pressure profile around the rational surface. The source term in the transport module is determined in such a way that the temperature profile at the stationary state corresponds to the input temperature profile in the transport module when the enhanced transport coefficient is not included. With the newly obtained temperature (pressure) profile, the equilibrium quantities are calculated again by the VMEC and then the MHD stability for the new equilibrium profile is evaluated. The procedure is repeated until the MHD stable equilibrium is obtained.

Figure 1 shows dependence of the achievable volume averaged beta value on the peaking factor of the pressure profile. For the ideal case, when the peaking factor σ is between 1.5 and 1.6, the achievable beta value is expected beyond 6%. In this case, the beta value is limited by MHD instabilities which has double rational surfaces. When σ is small ($\sigma \sim 1.3$), the achievable beta is small and the value does not depends on plasma resistivity. For $\sigma > 1.6$, the achievable beta value decreases as the resistivity increases. In the numerical model used here, the achievable beta value is 5.7% and 3.2% for $S=10^8$ and $S=10^7$, respectively.

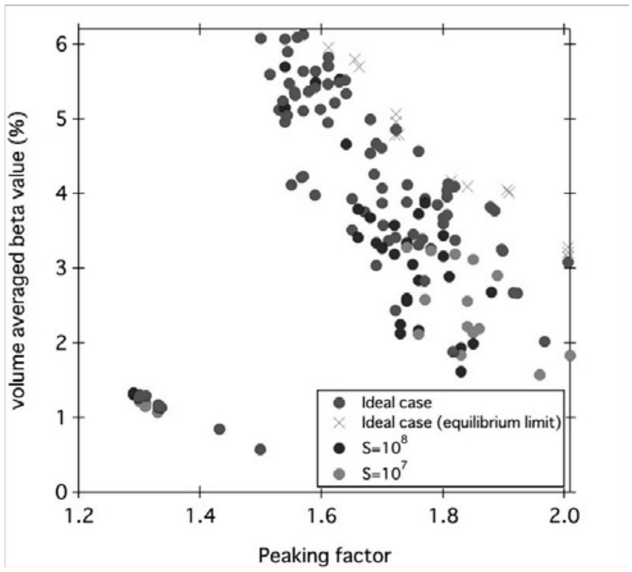

Fig. 1. Dependence of the achievable volume averaged beta value on the peaking factor. The cross and triangle points correspond to equilibrium limit.

1) M.Sato et al., Plasma Fusion Res. **3** (2008) S1063.
2) M.Sato et al., Proc. of 22nd IAEA Fusion Energy Conf. (Geneva, Switzerland,2008) IAEA-CN-165/TH/P9-18.
3) M.Sato et al., Contrib. Plasma Phys. **50** (2010) 665.