§2. Study of Effect of Number of Ideal MHD Modes for MHD Stability Beta Limit in LHD by TASK3D

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.

In order to explore the capability of the LHD configuration, the analysis of the achievable beta value from the perspective of the MHD stability is necessary. For the analysis of the "MHD stability beta limit"[1,2], 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 from the width of the eigenmode structure of the MHD instabilities. It is assumed that there is the upper limit of the poloidal mode number of the MHD instabilities, which directly affect the pressure gradient. In this study, the effect of the upper poloidal mode number m_c on the MHD stability beta limit has been studied.

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 ideal MHD stability is evaluated by the 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.

Fig. 1 shows the calculated quasi-stationary beta profile evaluated by using the experimental result where the volume averaged beta value is 4.8%. Here, the profile of the heating power is determined such that the experimental profile is reproduced by the simulation when the effect of the MHD instabilities is not included. When the modes with $m \leqq 4$ are assumed to directly affect the pressure gradient, the calculated stationary beta profile is almost same as the experimental profile. On the other hand, when the effect of the modes with $m \leqq 7$ or $m \leqq 10$ are included, the pressure profile close to the experimental profile cannot be maintained. Hence, m_c=4 is suitable for the upper limit of the poloidal mode number of the MHD instabilities which directly affect the pressure gradient.

Next, MHD stable equilibrium profiles have been calculated by TASK3D under the assumption that the modes with $m \leqq 4$ or $m \leqq 7$ directly affect the pressure gradient. Fig. 2 shows the dependence of the averaged beta value on the peaking factor of the pressure profile, σ. For $\sigma > 1.6$, the averaged beta value is limited by the equilibrium limit for both m_c=4 and m_c=7. When the peaking factor is between 1.5 and 1.6, the achievable beta value is about 6% for m_c=4. However, stable equilibrium profiles cannot be obtained for m_c=7. Hence, the MHD stability beta limit for $1.5< \sigma <1.6$ strongly depends on the number of MHD modes.

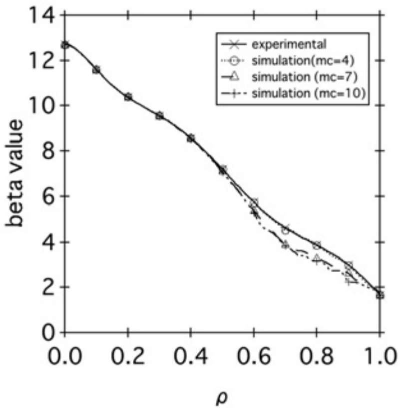

Fig. 1. Beta profiles of an experimental result for $<\beta>$=4.8% and numerical results for m_c=4, 7 and 10.

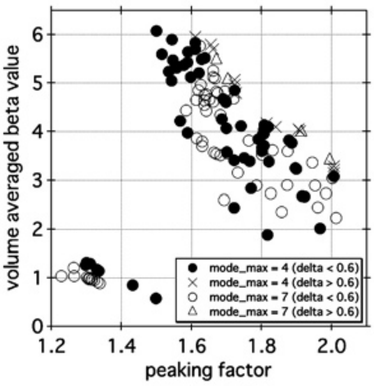

Fig. 2. Dependence of the achievable volume averaged beta value on the peaking factor. The cross and triangle points corresponds to equilibrium limit.

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