§20. Development of Numerical Scheme for Analysis of the MHD Stability Beta Limit in LHD by TASK3D

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The analysis of the “MHD stability beta limit” is studied by a hierarchy integrated simulation code TASK3D. In this study, 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. In the previous study[1)], the achievable beta value was expected to be beyond 6%. However, the achievable beta value was analyzed for only two types of the pressure profile due to cpu time limitation. In this study, the determination method of the source term profile in the transport module TR has been improved in order to reduce the calculation time. The improved numerical scheme allows the analysis for various types of the pressure profile[2)].

For the analysis of the “MHD stability beta limit”, 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 for simplicity, where the Suydam criterion is consistent with the Mercier criterion. The eigenmode structures obtained from the MSSH are used to evaluate the transport coefficient due to MHD instabilities in the transport module TR, where 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. That is, the transport coefficient χ is assumed as $\chi = \chi_0 + \chi_M$, where χ_0 is the transport coefficient for the case without the MHD instability and χ_M is the enhanced transport coefficient due to the MHD instabilities. Here $\chi_0 = 1\mathrm{m}^2/\mathrm{s}$ is assumed. The source term in the transport module S 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 due to MHD instabilities is neglected, i.e. $\chi = \chi_0$. 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 the dependence of the averaged beta value on the peaking factor σ of the pressure profile. Here it is assumed that the stability of the modes with $m \leqq 4$ are affected the pressure profile. For $\sigma > 1.6$, the averaged beta value is limited by the equilibrium limit. For $1.5 < \sigma < 1.6$, the achievable beta value is about 6%. However, it is not limited by the equilibrium limit. The eigenmodes for $\sigma \sim 1.5$ and $<\beta>\sim 6.1\%$ are shown in Fig.2. The mode with (m,n)=(3,1) is destabilized near the minimum of the rotational transform. Since the (m,n)=(3,1) mode causes the large flattening of the pressure gradient, the achievable beta value cannot reach the equilibrium limit when there are two rational surfaces of $\iota = 1/3$ for $<\beta>\sim 6\%$.

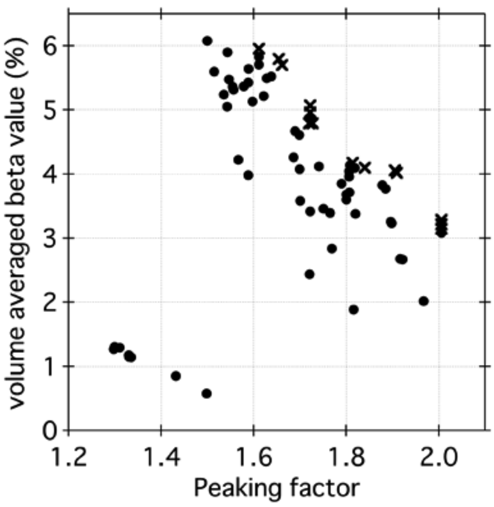

Fig. 1. Dependence of the averaged volume beta value on the peaking factor of the pressure profile. The data marked by x are corresponded to equilibrium limit.

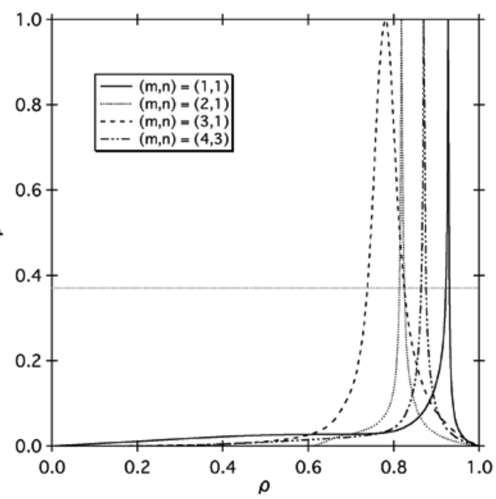

Fig. 2. The eigenmode structure of unstable interchange modes with $m \leqq 4$ for $<\beta>=6.1\%$.

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. (accepted)