§3. The Second Stability of the High-n Ballooning Modes in Heliotrons

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The boundary modulation induced by the free boundary motion of MHD equilibrium mainly appears as a large Shafranov shift of the whole plasma. Thus, it might be expected that the MHD stability is improved by the boundary modulation. In order to see how much the equilibrium is stable or unstable against high-n ballooning modes, high-n ballooning stability or $\iota' - P'$ stability diagram corresponding to $s - \alpha$ stability diagram in tokamak plasma are evaluated [1]by using the method of profile variations [2], where $\iota' = d\iota/d\psi$ and $P' = dP/d\psi$, respectively. Free boundary currentless MHD equilibria with $P(s) = P(0)(1 - s)(1 - s^9)$ (s is the normalized toroidal flux) are used for various vacuum plasma boundary in the inward-shifted LHD vacuum configuration. It has been found out that all the free boundary MHD equilibria with $\beta = 3\%$ or $\beta = 4\%$ are in the second stable region or strongly stable in the plasma core region, and near the marginally stable states in the plasma periphery against the high-n ballooning modes. Figure 1 shows the example of the $\iota' - P'$ stability diagrams in the plasma core region (the first row) and in the plasma periphery (the second row) for MHD equilibrium with vacuum boundary of $\iota_v = 1.48$. In those analyses, the radial wave number θ_k is set 0 and the most dangerous magnetic field line is selected in each flux surface. In Fig. 1, solid (dotted) lines indicate the marginally stability boundaries for MHD equilibrium with $\beta = 3\%$ ($\beta = 4\%$). Two rectangles in each graph indicate the location of the original surfaces for two β values, and the location moves along the direction of arrow as β increases. It is quite clear that the plasma core region is strongly stable against high-n ballooning modes, and that these properties do not change as β increases, namely, the core region has a tendency to move to the second stability region as β increases. On contrast to it, it is also clear that in the plasma periphery, the MHD equilibrium exists around the marginally stable state against the high-n ballooning modes. This tendency does not change in the range of β value used in stability analyses. Moreover, it might be expected that the MHD equilibria with higher β values still exist near the marginally stable states against high-n ballooning modes near the plasma periphery.

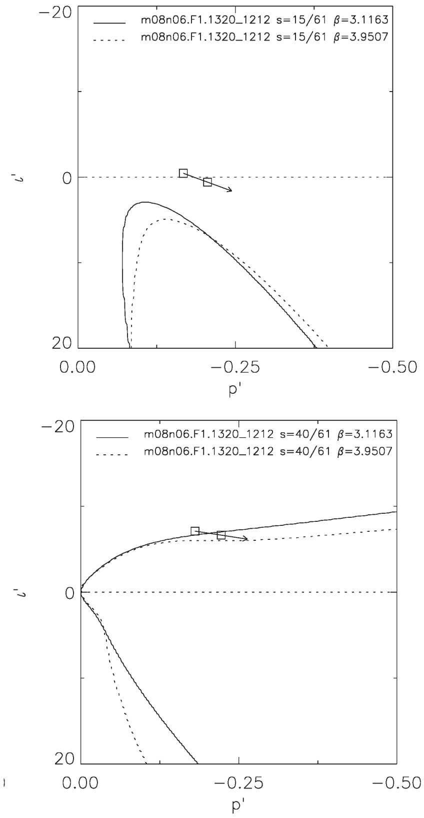

FIG. 1: Stability diagram of high-n ballooning modes in $\iota' - P'$ *plane at two flux surfaces in the plasma core (*$\rho = \sqrt{s} \sim 0.29$*, the first row) and in the plasma periphery (*$\rho \sim 0.82$*, the second row) for MHD equilibrium with vacuum boundary of* $\iota_v = 1.48$*. Note that since* ι *is negative in these analyses, the vertical axis has opposite sign to standard usage and* ι' *is positive (negative) in plasma core (periphery). Solid (dotted) lines indicate the marginally stable lines for* $\beta = 3\%$ *(*$\beta = 4\%$*). Rectangles denote the location of the original flux surfaces, and arrows show the direction of the change of the location with increasing* β*.*

[1]Nakajima.N,*et al.*,in Fusion Energy 2004 (Proc. 20th Int.Conf.Vilamoura,2004)IAEA,Vienna,TH/6.

[2]Hegna,C.C. and Nakajima,N., Phys.Plasmas **5** (1998) 1336.