§33. Onset of Pressure Driven Mode

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Relationship between characteristics of magnetohydrodynamic (MHD) modes and the linear stability boundary has been investigated by controlling the edge pressure gradient directly using the movable limiter. A series of experiments have three kinds of advantages on MHD study. One is that they enable us the detail reconstructions of equilibria with clear plasma boundary, which can give the accurate stability calculations. The LHD configuration has an ergodlc layer outside last closed flux surface, which makes the accuracy of the calculation of edge stability unclear. Second one is that the movable limiter can directly control the edge pressure and its gradient destabilizing the pressure-driven mode. Also it is useful for confirming them the resonant or non-resonant modes. Third one is that it is possible to identify the onset of MHD instability in steady state plasmas.

Changes of the plasma boundaries defined by different conditions and radial positions of rational surfaces as a function of the limiter position, $R_0$, are shown in Fig. 1. The $R_0$ is used here as a matter of convenience, which is the radial position of the limiter tip at $z = 0.33$ m. Clear identification of the plasma boundary in experiments is difficult because of the lack of measurements in the edge, so two kinds of plasma boundary are estimated here. One is defined by the extrapolation of observed $T_e$ profile, and the other are decided by the location where the plasma has the ratio of the specific amount of the electron stored energy to total one. The locations of resonant surfaces, which are calculated by 3-D MHD equilibrium code VMEC, are almost constant at any limiter position. Edge low-$n$ resonant surfaces with $m/n = 2/3$, $3/4$ and $4/5$ go outside plasma boundary when $R_0 < 4.13$ m, and the $\nu/2\pi = 1$ surface becomes just the plasma boundary at $R_0 = 4.02$ m. Thus, the pressures at $\nu/2\pi \geq 1$ resonant surfaces could be completely removed in the experiments.

The results of the linear stability analyses on resistive interchange mode and changes of magnetic Reynolds numbers, $S$, at $\nu/2\pi = 4/3$ and 1 resonances are shown in Fig. 2. The ideal interchange mode is theoretically stable in the edge region by the magnetic shear effect. The $D_{th}$ is well used as the index of stability boundary of the resistive mode. The positive $D_{th}$ means the resistive mode is unstable, and edge MHD modes are linearly unstable due to magnetic hill configuration in a series of experiments. When the $\nu/2\pi = 4/3$ and 1 resonant modes disappear or are sufficiently suppressed, both $D_{th}$s have the same value of $0.08 \sim 0.1$. The $S$ parameter, which concerns the linear growth rate of resistive modes, continues to decrease with the limiter insertion because of reduction of $T_e$. Both thresholds of the $D_{th}$ are obtained in the plasmas with $S \geq 5 \times 10^6$. According to Ref. 1, the low-$n$ resistive modes have the significant growth rate when $D_{th}$ is $0.15 \sim 0.20$ in the plasmas with $S \geq 10^6$, which is consistent with the experimental results within the factor of two.

Reference


Fig. 1 Changes of specific plasma boundaries and radial positions of resonant surfaces as a function of $R_0$.

Fig. 2 Changes of (a) $D_{th}$ and (b) $S$ around the $m/n = 1/1$ and $3/4$ resonant surfaces as a function of $R_0$. 