§3. Study of Stability Beta Limit in LHD

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In stellarators and heliotrons, interchange instability driven by pressure gradient is most concerned to impose the limit of the achievable beta value. Previous experiments in LHD show that high beta plasma with more than 5 % was successfully achieved in the moderately unstable regime where violated instabilities are benign and does not result in harmful consequence like disruption. The resistive interchange modes were dominantly observed in the all beta range because of magnetic hill in periphery, and it was verified that the amplitudes of modes were suppressed by an increment of the magnetic Reynolds number, *S*, which is favorable in fusion reactor regime with high electron temperature, $T_e$$^{1)}$. However, since the growth rate of the ideal interchange mode is independent of *S*, verification of the significance of the ideal stability boundary is still major problem to be solved in helical devices. Here we focus on the effect of the mode on the confinement property in the regime where the destabilization of the ideal interchange mode is predicted by linear theory.

The access to the ideal-unstable regime is possible by enhancing magnetic hill and/or by reducing the magnetic shear. The former can be realized by shifting the magnetic axis position to the inward, while the latter is by reducing the plasma aspect ratio and increasing plasma current. The objective modes are m/n = 2/1 and 1/1, respectively. Figure 1 shows MHD activities in the reduced magnetic shear configuration. The plasma current is induced by neutral beams in order to decrease the magnetic shear in the high plasma aspect ratio configuration with low shear. While the bursts of the m/n = 1/1 mode appear and drop the central beta, the mode rotation slows down when the plasma current exceeds a threshold $^{2)}$. The minor collapse occurs after the stop of the rotation at 4.5 s. The T_e profiles before and after the collapse are shown in Fig.4. The rotating m/n = 1/1 mode forms the T_e profile flattening around the $\iota/2\pi$ = 1 resonance. The central T_e is significantly dropped by the extension of the flattening. It was found that this tendency was similar to the enhanced magnetic hill configuration.

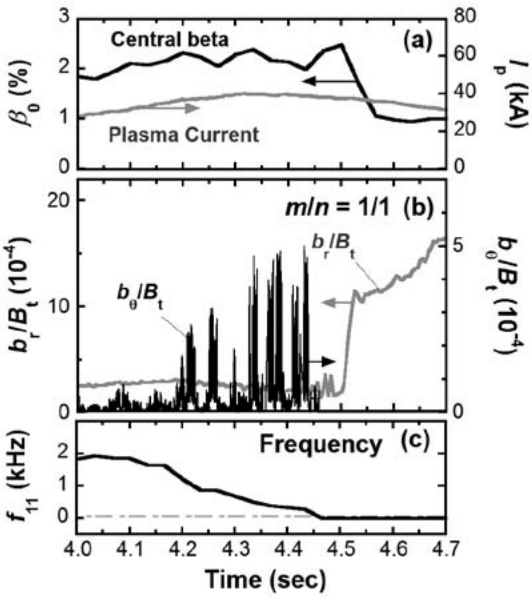

Fig. 1 Time evolutions of (a) central beta and plasma current, (b) amplitude of m/n = 1/1 mode and (c) frequency in a typical discharge in reduced shear configuration.

Figure 2 shows changes of central beta and the formation of the profile flattening as a function of the mode frequency. The m/n = 2/1 and 1/1 activities were obtained in the enhanced magnetic hill configuration and reduced magnetic shear one, respectively. In the m/n = 2/1 case, the flattening structure width normalized by the minor radius is increased to 0.1 when the frequency is decreased to 0.4 kHz, and the central beta starts to decrease simultaneously. The m/n = 1/1 mode forms the flattening structure when the frequency is dropped to 0.9 kHz, and it is linearly extended with the decrease in the frequency. When the frequency reaches zero, the flattening width approached to more than 0.5, which causes the degradation of central beta by about 60 %.

This study clarified the impact of low-*n* MHD activities on the plasma confinement in ideal unstable regime in order to find the achievable beta regime for helical reactor. The low-*n* instabilities deforming the plasma profile appeared when the magnetic shear was reduced or the magnetic hill is enhanced. The minor collapse decreasing the central beta to at most 60 % occurred when their mode rotations were stopped.

1) Sakakibara, S. et al.: Plasma Phys Control. Fusion 50 (2008) 124014.
2) Sakakibara, S. et al.: Nucl. Fusion 53 (2013) 043010.

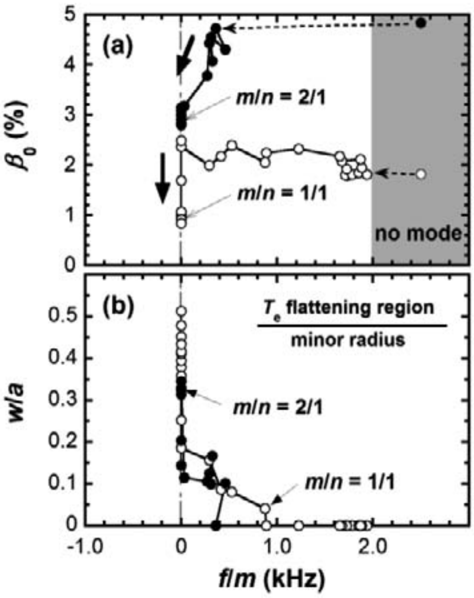

Fig. 2 Changes of (a) central beta and (b) ratio of the flattening region to minor radius as a function of normalized mode frequency.