§34. Influence of MHD Instabilities on Confinement Performance in LHD

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In the LHD experiment to extend the beta regime to the reactor-relevant high-beta plasmas with the 5% volume averaged toroidal beta value for long time, ~100 times of the energy confinement time without disruptive phenomena. During the globally stable, long-sustainment phase, the low-order magnetic fluctuations resonated with the peripheral rational surfaces, where the magnetic hill configuration persists even in high-beta regimes, have been observed. On the effects of the fluctuations on the confinement, the fine local flattening structures around the peripheral rational surfaces in the temperature profiles are observed together with the low-order fluctuations[1]. However, the quantitative influence has not been clear.

In order to quantitatively evaluate the influence of the global MHD instability on the confinement performance, we compare the energy confinement time between just before global MHD instability disappears and after that, and discuss the relationship between the gradation level of confinement performance and the saturated internal structure of the MHD fluctuation estimated by the multi-channel soft X-ray (SXR) measurement. Here we concentrate our attention on the edge resonant m=1/n=1 mode, where m and n are the poloidal and toroidal mode numbers of the MHD instability, respectively, because the m/n=1/1 magnetic fluctuations are observed in the almost whole LHD high-beta discharges, their radial mode width is theoretically predicted larger than the pressure driven MHD instabilities with shorter poloidal wave length, the situation of which is favorable to measure the instability's saturated mode structure. In Fig.1, three different discharges are shown to see the dependence of confinement degradation evaluated from the time evolution of the normalized HISS04 factor. In Fig.1 (a), where the magnetic fluctuation level is ~0.008%, the appearance of the m=1/n=1 mode at t=2.69s does not cause any degradation of the H factor. When the magnetic fluctuation level is ~0.04%, as shown in Fig.1 (b), the H factor is degraded by ~5% as the mode appears. In this case, the total magnetic field intensity B_0 is 1.375T, lower than the case in Fig.1 (a) with B_0 of 1.75T. And <β> in Fig.1 (b) is ~0.5%, lower than the case in Fig.1 (a) with <β>~1%. In Fig.1 (c), the m=1/n=1 mode brings the further degradation, up to 10%. In this case, the magnetic fluctuation level is almost the same as in Fig.1 (b), but with lower B_0 of 0.9T and higher <β>~1%. Figure 2 shows the summary of the relationships between the saturated internal mode structures as characterized by the mode width and the amplitude maximum of the radial displacement. The mode width and the amplitude maximum of the radial displacement are estimated from the SXR measurement as shown in ref.[2]. Figure 2 suggests that amplitude maximum of saturated radial displacement is strongly related with degradation level of confinement performance due to the low-n instability. The m=1/n=1 mode amplitude is a good index to characterize the effect of the mode on the degree of confinement degradation.

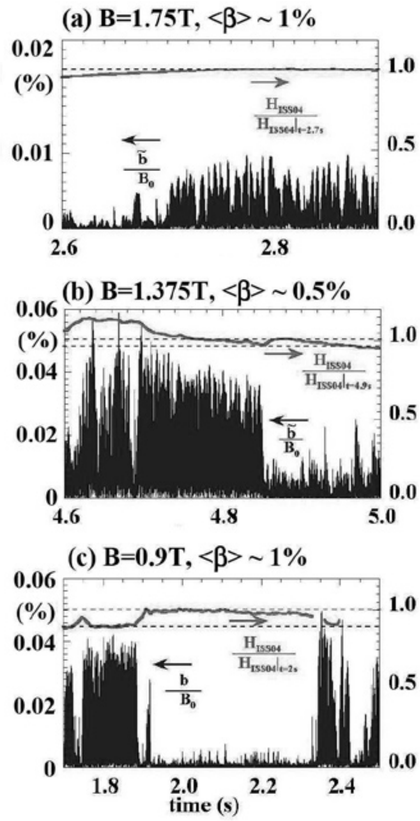

Fig.1. Time evolution of the m=1/n=1 magnetic fluctuation level normalized by operational magnetic field strength B0 and the confinement performance based on the ISS04 empirical global energy confinement time scaling.

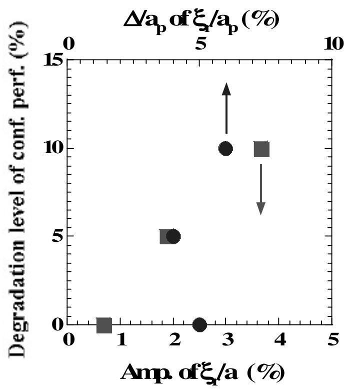

Fig.2. Degradation level of confinement performance based on the ISS04 empirical scaling versus amplitude maximum and mode width of radial displacement.

[1] S. Sakakibara et al., Plasma Phys. Control. Fusion 50 (2008) 124014.
[2] Watanabe, K.Y. et al, Phys. Plasma 18 (2011) 056119.