§7. Development of a Real Time Control System for MHD Instabilities

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In LHD, the most important instability is the resistive interchange mode arising from the magnetic hill configuration near the plasma edge. In fact, edge modes with low-mode number sometimes grow in a regime where $\beta > \sim 4\%$. The aims of this research include understanding the mechanism of growth and saturation of this mode, and designing a real-time control system for this particular mode as a part of the high-beta plasma research in LHD. We started development of a MHD control system for high-β plasmas. As a test bench, we have used the RFP configuration, where current-driven tearing or kink instabilities are the most important. even in high-β regime.

In a low-aspect-ratio machine RELAX[1], feedback control of localized m=1 field errors has been performed with a pair of analog feedback controllers and pulsed current drive circuits using IGBTs as fast switching elements. Figure 1 shows the effect of feedback control, demonstrating that the RFP performance could be improved with suppression of the m=1 radial magnetic field at the gap[4]. The field errors have been suppressed to < 0.5mT during the flat-topped current phase. The reduced control capability after ~1.5ms is due to the capability of the present current drive circuits. The analog control is equivalent to the (localized) virtual shell scheme[2]. The same scheme will be applicable to a designed feedback control system with 4(poloidally)×8(toroidally) segmented coils covering a half of the outer vacuum vessel surface area of RELAX machine.

In LHD experiments, the relationship between low-n magnetic fluctuations and internal structure of the associated MHD mode has been studied. In order to analyze internal structure of the MHD mode, the following procedure has been applied using SXR data from the SBD arrays[3]. Fluctuating components of the SXR signals in the frequency region where coherence with the m=1/n=1 magnetic fluctuation is high (> 0.7) are extracted, and radial profile of the SXR fluctuation has been obtained. The following radial structure was assumed,

$$\tilde{i}_{\rm sx} = \frac{\partial \bar{i}}{\partial \rho} A_0 \exp\{-(\frac{\rho-\rho_{\rm peak}}{\Delta})^2\}\cos(m\theta_{\rm B}+2\pi f t)$$

The mode width Δ and mode amplitude A_0 have been determined so as to minimize the RMS deviation of the reconstructed SXR chord profile from the experimental one. It is clear in Fig.2 that Δ increases as the magnetic mode amplitude is increased, with a trend of weak saturation in the higher amplitude regime. When we regard the m=1/n=1 island width deduced from the electron temperature profile with Thomson scattering as the mode width in much higher amplitude region ($\tilde{b}/B_t \approx 40\times10^{-5}$), the data points in these two regions are smoothly connected by the approximate formula, $\Delta \propto \tilde{b}^{0.5}$. When combined with experimental dependence of the magnetic fluctuation amplitude on the magnetic Reynolds number S ($\tilde{b} \propto S^{-0.7}$), we obtain the following dependence $\Delta \propto S^{-0.35}$, which is consistent with the prediction of the linear theory of resistive interchange mode, $\Delta \propto \beta^{1/6} S^{-1/3}$.

1) S.Masamune et al., Proc. 22nd IAEA Fusion Energy Conf., Geneva, 7E/1-Rb (2008).
2) S. Masamune, J. Plasma Science and Nuclear Fusion Research, Vol. 84, No.11, pp.766-770 (2008).
3) Y. Takemura, K.Y. Watanabe et al., Proc. 25th Annual Meeting of JSPF, 2aB14P (2008).
4) T. Yamashita et al., Proc. 25th Annual Meeting of JSPF, 5aB22P (2008).

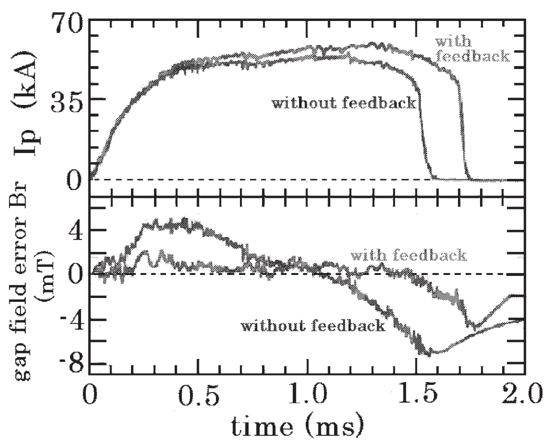

Fig.1: Feedback control of localized field errors has improved discharge performance in RELAX. The control scheme corresponds to (localized) virtual shell.

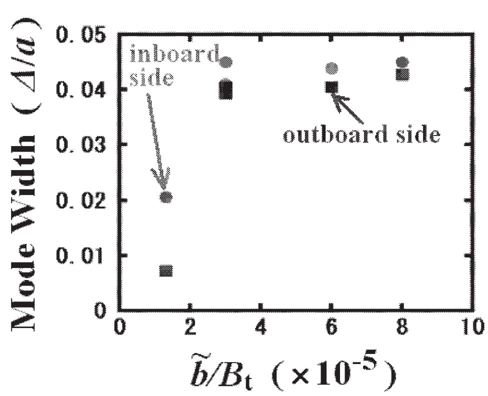

Fig.2: Normalized width (Δ/a) of the m/n=1/1 mode estimated from SXR data vs. magnetic fluctuation amplitude of the corresponding mode.