§11. Control of Energetic-Particle-Driven MHD Instabilities by ECH/ECCD

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Understanding and control of MHD instabilities is an important issues for production and sustainment of high performance plasmas in toroidal fusion devices. High-energy alpha particles generated at burning process and ions produced by neutral beam injection heating, having velocity comparable to Alfven velocity, interact with shear Alfven waves during their slowing down process, resulting in excitation of MHD instabilities. Control of energetic-particle (EP) -driven MHD instabilities by electron cyclotron resonance heating (ECRH) and current drive (ECCD) has been experimentally studied in the DIII-D tokamaks and the TJ-II and Heliotron J helical devices. In the Heliotron J experiment, we have successfully demonstrated stabilization of an energetic particle mode (EPM) by controlling the rotational transform profile by ECCD[1)]. Main purposes of this study are to stabilize EP driven modes by ECRH/ECCD in LHD and to clarify the physical mechanism. We expect that the stabilization of EP driven instabilities will help suppress EP loss.

We have analyzed experimental results on stabilization of Alfven Eigenmode (AE) by ECH in LHD. For the experimental condition of B=-1.375T, n_e~ 0.8 x 10^{19} m^{-3}, we applied ECH of 2-O (1.1MW, rho~0.6), 5.5-U (1.1MW, rho~0.0) and 9.5-U (1.0MW, rho~0.0), and NB1 (co), NBI2 (ctr), NBI3 (ctr). Figure 1 shows time evolution of Fourier spectrum. The ECH power is applied to an NBI plasma. It can be seen that stabilization effect of the EC power, 1 MW (one gyrotron), is weak for an AE around 260kHz (n=1), while full ECH power is effective for the stabilization. We have observed time delay of the AE response to ECH, which may be closely related to slowing down time of energetic ions. For another AE with lower frequency, 210 kHz (n=0), we have observed the opposite effect, that is, destabilization effect.

When ctr NB power is decreased as shown in Fig. 1 (b), an AE around 210 kHz is excited. In this case, the AE is fully stabilized by second harmonic X-mode ECRH (rho~0.0). The mode stabilization is modulated according to the ECRH power modulation. No other AE has been excited, which is contrast to the former experimental results. The possible mechanism is that the stabilization by ECH may be connected to the excitation position of AEs.

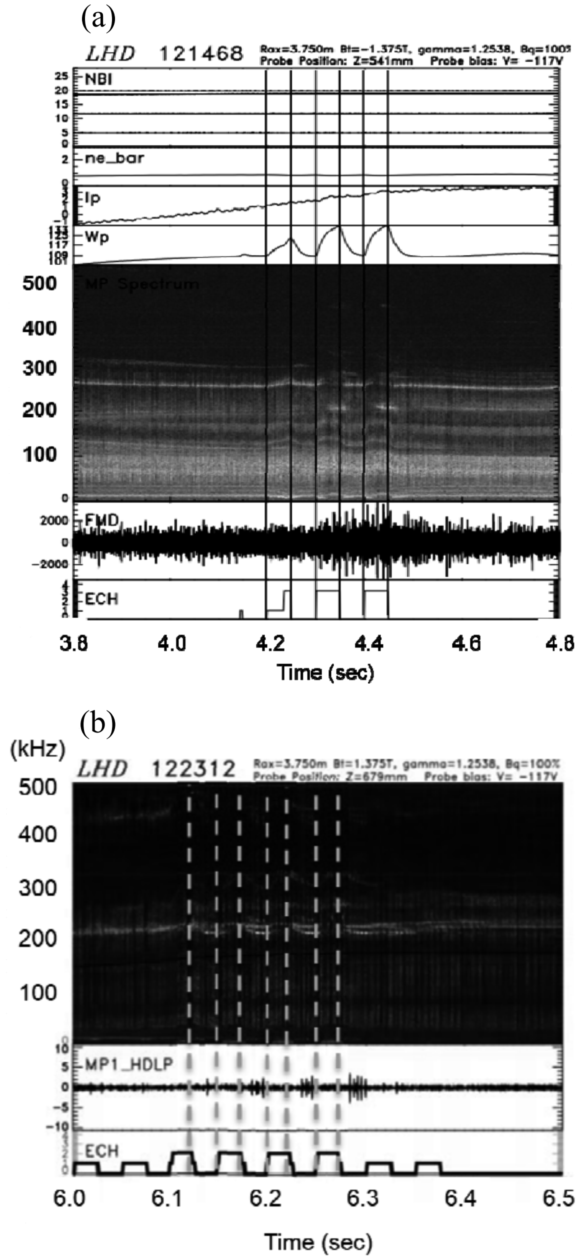

Fig. 1. Response of Alfven eigenmodes to modulated ECH, at (a) NBI2 (ctr) and NBI3 (co) and (b) NBI1 (ctr)."

1) Nagasaki, K. et al.: Nucl. Fusion 53 (2013) 113041
2) Yamamoto, S. et al., 25th IAEA Fusion Energy Conference, Saint Petersburg, Russia, Oct. 13-18, 2014, EX/P4-27