§60. Studies of Characteristics of Helicity-induced Alfvén Eigenmodes in LHD Plasmas

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To clarify the characteristics of energetic ion driven MHD instabilities, which can be excited by super-Alfvénic ions produced by NBI/ICRF and D-T fusion reaction, and to minimize their effect on energetic ion transport and/or loss are key issues for the realization of DT fusion reactor. Toroidicity induced Alfvén eigenmodes (TAEs) and energetic particle modes (EPMs) are actively and extensively investigated in both tokamak and helical plasmas. The detail of them and their effect on energetic ion transport and/or loss are clarifying. In LHD plasma, TAEs/EMPs and energetic ion loss cause by TAEs/EMPs are also observed in NBI-heated plasmas. Moreover, we observed high frequency mode of which frequency about five times higher than that of TAE in the low magnetic field condition $B_t < 0.75$ T. The high frequency mode was successfully identified as helicity induced Alfvén eigenmodes (HAEs) by the comparison between observed frequency and shear Alfvén spectra where three dimensional magnetic field structures are taken into account. LHD has three-dimensional magnetic field of which strength vary in both poloidal and toroidal direction. The variation of magnetic field strength in the poloidal and toroidal direction simultaneously induce the poloidal and toroidal mode coupling of shear Alfvén spectra. Then HAE gaps are produced and HAE can be existed in HAE gap. The frequency of HAE gap is proportional to toroidal field period N_p and inversely proportional to rotational transform. The rotational transform of LHD increases from plasma core region towards edge. Therefore, the frequency of HAE at plasma edge is lower than 250 kHz in the condition of $B < 0.75$ in LHD plasmas. In the experimental campaign of FY2000, HAE has been observed only in the inward shifted magnetic configuration R_{ax}=3.6m of which edge rotational transform is the highest in the magnetic configuration. The HAE was observed in other configurations in recent experiment campaign because energetic ion beta was increased by the upgrading of NBI. Figure 1 shows typical observation of HAE in NBI heated LHD plasmas. We observed a lot of modes including EPM, TAE in low frequency range ($f < 250$ kHz) and HAE in high frequency range ($f > 250$ kHz) in Fig.1. In the previous experiments of LHD, We have measured the high frequency MHD instabilities using magnetic probe measurements with resonance frequency ~ 500kHz determined by LCR electrical circuit and sampling frequency 1MHz. We attempted to measure the MHD instabilities of which frequency is higher than that of 1MHz using newly developed high frequency magnetic coils. Figure 2 shows the time evolution of magnetic fluctuation obtained from above mentioned high frequency magnetic coils. We can measure the magnetic fluctuation in the toroidal direction, which is different from poloidal direction measured by usual magnetic probes. We see high frequency mode in the range of < 300kHz in expanded view in Fig. 2. However, the magnetic fluctuation corresponding to MHD instabilities in the range of > 300kHz are invisible in Fig.2. In general speaking, it is easy to measure high frequency mode compared with low frequency mode because magnetic measurement can measure the change of magnetic field in time dB/dt. We concluded that high frequency mode of which frequency is higher than that of usually observed HAE are stable in this configuration of LHD experiment.

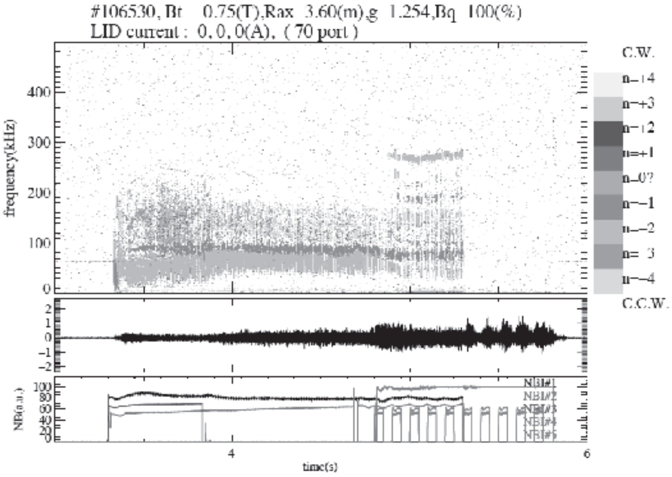

Fig. 1. Time evolution of magnetic fluctuation of HAE in NBI heated LHD plasmas.

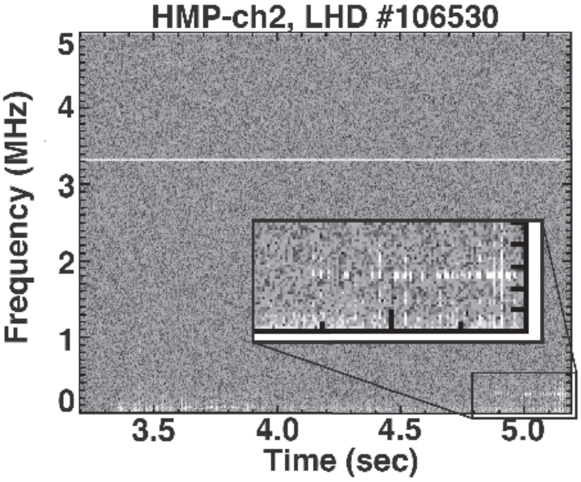

Fig. 2. Time evolution of magnetic fluctuation in high frequency magnetic coil. The discharge is same as Fig. 2.