*35th EPS Conference on Plasma Phys. Hersonissos, 9 - 13 June 2008 ECA Vol.**32D**, P-5.101 (2008)*

Tearing mode suppression by ECRH in the HL-2A tokamak

X.Q. Ji, Q.W. Yang, W. Deng, J. Zhou, B.B. Feng, B.S. Yuan, W.M. Xie, Y. Liu

Southwestern Institute of Physics, Chengdu, China

1. Introduction

When tearing mode instability occurs in plasma, magnetic field lines are broken and reconnected to form magnetic islands, which can lead to confinement degeneration, even discharge disruption. The instabilities need to be controlled for the achievement of high performance plasma. Tearing mode stabilization by Electron Cyclotron Resonant Heating /Current Drive (ECRH/CD) has been performed in several tokamaks, such as ASDEX Upgrade[1], DIII-D[2], JFT-2M[3], T-10[4], TFR[5] and TEXTOR[6]. ECRH and ECCD attract particular attention because of their excellent localization. In the JFT-2M tokamak, the m/n=2/1 modes are always suppressed by ECRH when the ECR layer is set correctly on a narrow region near the q=2 surface, where m and n are the poloidal and toroidal mode numbers, respectively. In T-10, the experiments on the 2/1 mode stabilization by ECRH can well be explained by the effect of profile modification. However, in the TFR tokamak the mode suppression likely depends on the outward shift of the plasma column caused by ECRH. In addition, the interaction between the superthermal electrons produced by ECRH and the 2/1 mode has been studied in TEXT.

In HL-2A, the 2/1 tearing mode stabilization by ECRH has been carried out. In this paper, the effectiveness of ECRH technique on the 2/1 mode suppression is demonstrated and the mechanism of the 2/1 tearing mode stabilization by ECRH is analyzed.

2. Experimental arrangement

The HL-2A tokamak (with major radius of R=1.64m and minor radius of a=0.4m) is a middle size tokamak. One set of Mirnov probes is equipped. A poloidal array of 18 and a toroidal array of 10 pick-up coils are used to measure the poloidal and toroidal perturbation field. And high resolution soft X-ray (SXR) is used to analyze MHD activity. From these experimental data, the mode frequency, amplitude and magnetic island size have been investigated.

A second harmonic X-mode ECRH system at 68 GHz, delivering up to 2MW by 4 gyrotrons, has been brought into operation in the HL-2A tokamak. The beam is injected from low field side. The ECR power is located at the magnetic axis where toroidal field B_t=1.21T. By changing toroidal field, the location of ECR power deposition can be adjusted for the tearing mode stabilization.

3. Experimental results

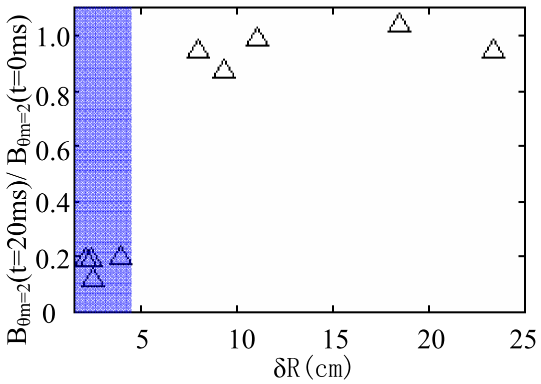

Fig.1 Variation of the perturbation field change with the location scan of ECR power deposition. I_p~166kA,

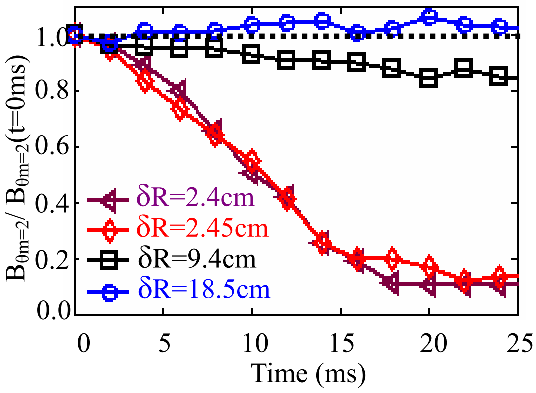

Fig.2 Evolution of the amplitude of $B_{\theta m=2}$/ $B_{\theta m=2}$(t=0ms). I_p=165kA, P_{ECRH}=220kW. ECRH is turn on at t=0.

In HL-2A, the investigation on 2/1 mode suppression by ECRH has been performed with following parameters: plasma current I_p~165 KA, P_{ECRH}~220KW, q_a~3.5-4, line averaged electron density $\langle n_e \rangle \sim 1\times10^{19} m^{-3}$. A location scan of ECR power deposition (B_t=1.23~1.4 T) has been realized on HL-2A. As shown in Fig.1, the behaviors of the 2/1 modes are very sensitive to the position of ECR power deposition, where $B_{\theta m=2}$(t=20ms)/ $B_{\theta m=2}$(t=0ms) is the change of perturbation field, $B_{\theta m=2}$(t=20ms) and $B_{\theta m=2}$(t=0ms) are the perturbation field 20ms and 0ms after ECRH switches on, here the perturbation field is measured by Mirnov probes. The 2/1 modes can only be suppressed by ECRH which is set on a narrow region near the q=2 surface (the shade region in Fig.1). Where $\delta R=R_{q=2}-R_{dep}$, $R_{q=2}$ and R_{dep} are the radius of q=2 surface and ECR power deposition. The position of q=2 surface can be estimated by SXR and Equilibrium FIT (EFIT) in HL-2A. The detail evolution of $B_{\theta m=2}$/ $B_{\theta m=2}$(t=0ms) with different δR is shown in Fig.2. When the power is deposited near the islands (such as: δR=2.4cm, δR=2.45cm), $B_{\theta m=2}$ reduces since ECRH switches on, about 15ms later the amplitudes of perturbation field are below 20% of $B_{\theta m=2}$(t=0ms). In Fig.2, when δR=18.5cm, the mode was slightly enhanced by ECRH.

Fig.3 shows the time traces of shot:8233. The deposition of ECRH is far away from the

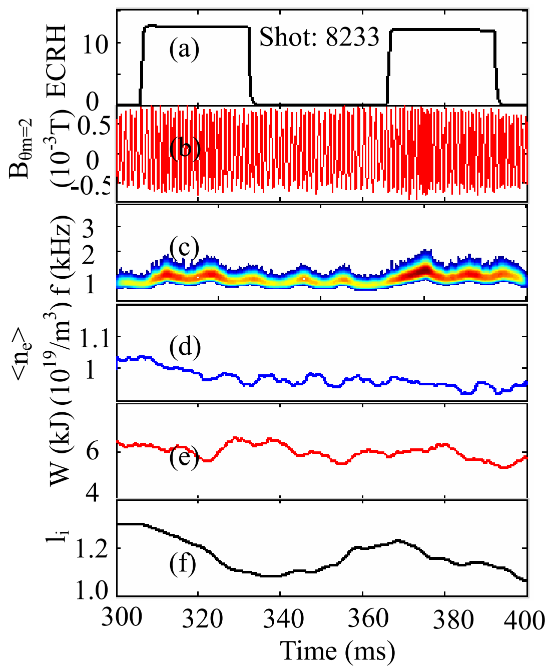

Fig.3 Typical time traces of a shot which the ECR power deposits far away from the island. I_p=166kA, B_t=1.34T,

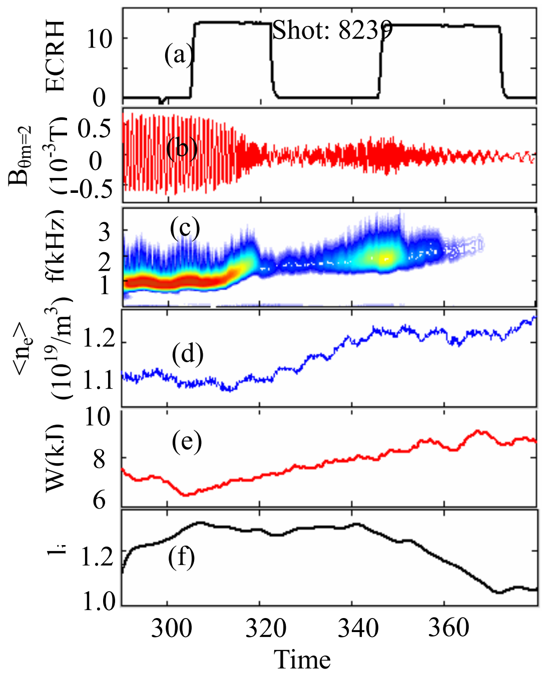

Fig.4 Time traces of shot:8239 which the 2/1 mode is suppressed by ECRH. I_p=168kA, B_t=1.385T. P_{ECRH}=220kW

resonance surface (δR~11cm). During ECRH, no obvious effects are found on the amplitude of the mode, the line average density and the stored energy, except that the frequency of the mode increases (Fig.3 (c)). However, the typical shot of mode suppression by ECRH is shown in Fig.4. In this discharge, the ECR power is deposited near the q=2 surface (δR~2cm). During the first ECRH pulse, the mode is partially suppressed, the particle and energy confinement improve ($B_{\theta m=2}$reduces, while the density and stored energy increase obviously). As shown in Fig.4(b) and Fig.4(f), the plasma internal inductance (l_i) decreases slightly when the mode suppression occurs in the first ECRH pulse. It means that the mode stabilization is not due to the global change of current profile, but the local ECRH effect. Moreover, from the fact that the mode can only be suppressed when the power deposits near the islands, we estimate that the direct island heating is the basic mechanism of the mode suppression by ECRH. ECRH power deposited near the 2/1 island increases the conductivity ($\sim T_e^{3/2}$), the current density redistributes, this influences the mode stability.

During the second ECRH pulse in Fig.4, the amplitude of the mode decreases continually, while l_i decreases clearly (Fig.4(f)), finally the mode is completely suppressed (the mode does not enhance when the ECRH switches off). The complete mode suppression has been found in some discharge with long pulse ECRH (Fig.5). In the similar plasmas, the variation in the 2/1 mode behavior for different length of ECRH has been investigated. The power is deposited near the islands in these two discharges. In shot:8239, the length of ECRH pulse is less than 20ms, after the ECRH turns off, the amplitude of mode increases. On the contrary, the mode can be completely suppressed if the ECRH pulse is long enough. In shot:8207, about 25ms after ECRH injection, the mode is completely suppressed, and the sawteeth appear (which means the global change of current profile). From these experimental results, we propose that the global current profile redistribution caused by long pulse ECRH leads to the complete mode suppression.

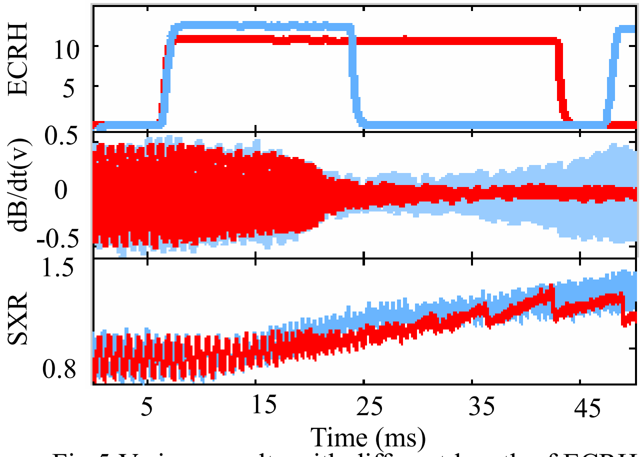

Fig.5 Various results with different length of ECRH pulse. Red: shot8207; blue: shot8239. I_p~166kA, B_t~1.39T.

4. Conclusion

In HL-2A, experiments show the effectiveness of the 2/1 mode suppression by ECRH. The necessary for mode suppression by ECRH is that the power should be deposited near the islands. And, the mode can be completely stabilized if the ECRH pulse is long enough. From the experiments, it seems likely that the mechanism of mode stabilization is mainly due to the direct island heating by ECRH in HL-2A. And the change of global profile caused by long pulse ECRH is the important factor on mode stability.

References

1. H. Zohm et al., Phys. Plasma 8 (2001) 2009.
2. R.J. LaHaye et al. Phys. Plasma 9 (2002) 2051.
3. K. Hoshino et al., Phys. Rev. Lett. 69 (1992) 2208.
4. D. A. KISLOV et al., Nucl. Fusion 37 (1997) 339.
5. TFR Group and FOM ECRH Team. Nucl. Fusion 28 (1988) 1995.
6. E. Westerhof et al., Nucl. Fusion 47(2007) 85.