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The Characteristics of Magnetic Oscillations in L-H Transition and Disruption in JFT-2M Tokamak

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ABSTRACT

The observed characteristics of magnetic oscillations in L-H transition and disruption are described. Two kinds of MHD magnetic probes are used in order to cover broadband frequency range from 1.3 kHz to 300 kHz in the H-mode. Depending on the probe's position and frequency, different characteristics are observed. Precursor like oscillation in L-H transition, and the difference between sawtooth and ELM are discussed. All disruptions during the current rising phase are related with m=2 or m=3 mode. Different disruption characteristics for different operation conditions could be found in the MHD probes.

1. Introduction

It is considered that H-mode and disruption are inevitable phenomena in operation of tokamak until now. H-mode is considered as one of the most promising confinement regime in the future tokamak, on the other hand disruption is considered as one of the worst phenomenon that must be avoided. In spite of intense studies about them both experimentally[1,2] and theoretically[3,4], their phenomena are not clearly understood until now.

H-mode is mainly related with plasma and wall interactions. H-mode is characterized as a formation of improved confinement zone at the plasma boundary. It results in a subsequent increase of plasma temperature and density. Disruption especially in the current rising phase is usually occurs with mode locking phenomena[5]. Despite the stabilizing effect of the wall, mode locking induces some impurities into the plasma from the wall. This makes the state worse, and finally it results in disruption.

The MHD magnetic probes are very useful in detecting the global plasma-wall interaction near the plasma edge in the tokamak. The characteristics of magnetic oscillations in L-H transition and disruption in JFT-2M are investigated in this study. Magnetic oscillations are checked mainly by MHD probes. The frequency range between 1.3 kHz and 300 kHz are checked in the H-mode. Depending on the position of the probe, different informations could be found even in the same shot. Precursor like oscillations could be found in some magnetic probes just before the starting of the H-mode. The frequency range between 1.3 kHz and 20 kHz are checked in the disruption. Depending on the operation conditions, some typical characteristics of disruption could be found. Experimental arrangement of this study is described in Chap. 2. And the observed characteristics in H-mode and disruption in different operation regimes are described in Chap. 3 and Chap. 4.

2. Experimental Arrangements

JFT-2M is a medium size tokamak with graphite limiters and stainless steel divertors. The major radius of the vacuum vessel is 1.31 m and minor radius is 0.3 m in the divertor configuration. There are two kinds of MHD magnetic probes inside the vacuum vessel. One is for the detection of low frequency(LF) MHD characteristics and the other is for the detection of high frequency(HF) characteristics. The characteristics of frequency range around 1.3 - 20.0 kHz are covered by LF probes, and those of around 20.0 - 300.0 kHz are covered by HF probe. The limits of covered frequency comes from probe specification, noise level and time resolution of DAS. HF probes are made with small turns(25 turns) and rare shielding. Low pass filter(cutoff frequency; 20 kHz) and isolation amplifier were used in the signal processing of low frequency. The noises from SCR switches were eliminated by software filter where fast Fourier transforms(FFT) are used. The frequencies of 600 Hz and 1.2 kHz are the main noises of MHD probes in JFT-2M. Low pass filter(cutoff frequence; 1 MHz), high pass filter(cutoff frequence; 20 kHz) and amplifiers were used in the signal processing of high frequency.

In the LF analysis 50 kHz sampled data during 320 msec were used. This samplings were done in order to analyze the characteristics of L-H transition and disruption. In the HF analysis 1 MHz sampled data during only 16 msec were used because of DAS limitations. HF analysis was done in the H-mode. The mode numbers have been calculated with 15 poloidal(BP) probes and 3 normal(BN) probes in the disruption analysis. BP probes were used in calculation of m, and BN probes were used in calculation of n. The toroidal angles between the BN probes are 90 degrees. The positions of the magnetic probes in JFT-2M are shown in Fig. 1. The data processing procedures used in analysing the magnetic probe signal include the following operations:

(1) Digitizations of the magnetic probe signals;
(2) Elimination of noises with FFT;
(3) Extraction of interested frequency data with FFT;
(4) Figure and mode number calculation if possible.

3. Characteristics in L-H Transitions

(1) Low Frequency Characteristics

Fig. 2 is the contour plots of magnetic probe signals, which represent the characteristics of OH and H-mode in the frequency range between 1.3 kHz and 20.0 kHz. There was no NBI heating in #81784. During the ohmic heating, there are stable oscillations around 7.0 kHz and 14.0 kHz. But if NBI injection is done, the above characteristic frequencies are reduced and broadened clearly. H-mode is sustained during more than 50 msec in #81788. The characteristic MHD oscillations are abruptly disappeared in the L-H transition. The amplitudes of MHD oscillations are clearly reduced during H-mode in all frequency ranges. Low frequency and low amplitude oscillation around 3 kHz could be seen during H-mode. After the end of H-mode, the oscillation frequency increases gradually until the characteristic frequencies of ohmic heating are recovered again. This is absolutely opposite characteristics compared with that of disruption. But the amplitude of the oscillation do not increase with time in the L-H transition.

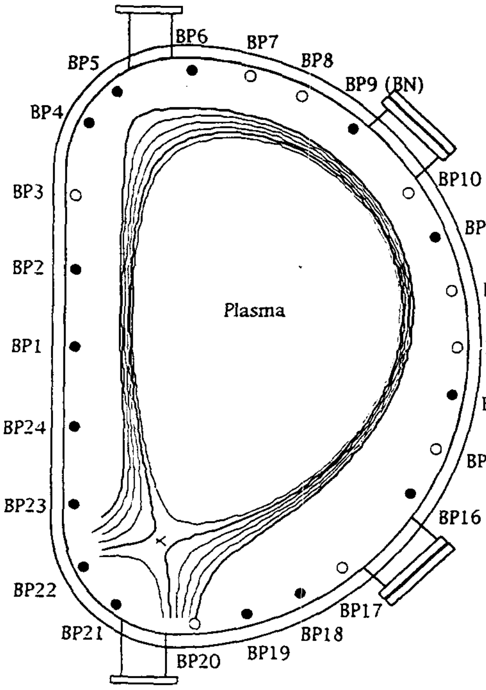

Fig. 1 The positions of the MHD probes in JFT-2M

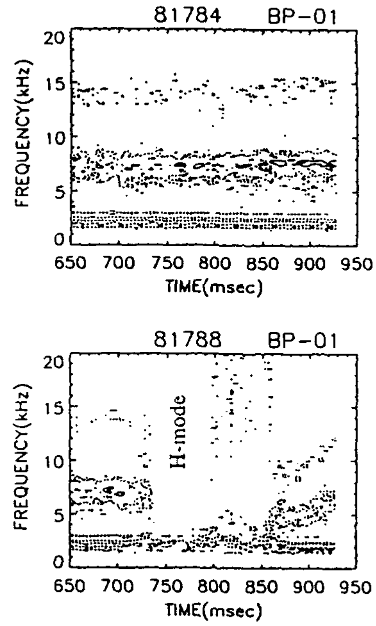

Fig. 2 The contour plots of the MHD probe signals in OH and H-mode(LF case).

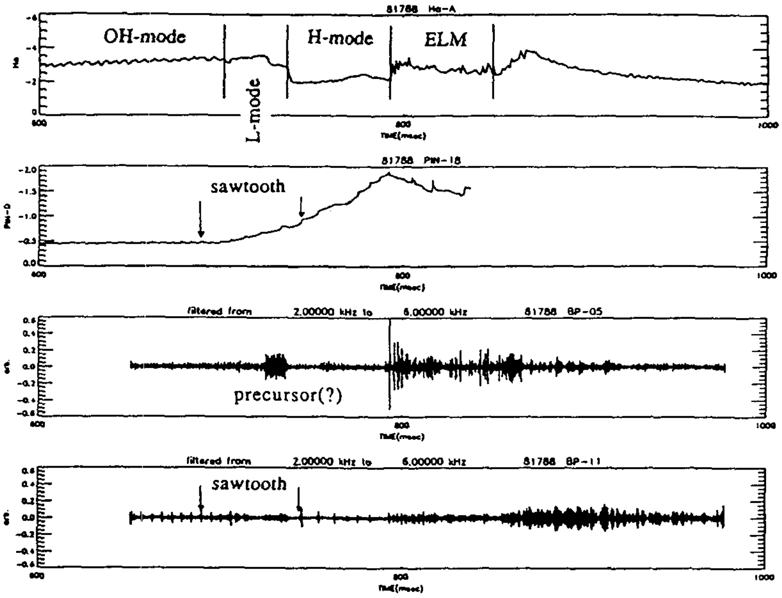

Fig. 3 Time evolution of H_α, PIN diode, and probe signals in the L-H transition. NBI was given from 700 msec to 850 msec.

Depending on the position of the magnetic probe, different characteristics could be seen. The time evolution of H_{α}, PIN diode, and probe signals of different positions are shown in Fig. 3. Sawteeth are clearly seen in the outer side probes. Significant differences are there in the amplitude of this oscillation depending on the poloidal position. The oscillations caused by sawteeth completely coincide with the abrupt increases in the PIN diode signals. On the other hand precursor like oscillations of H-mode [6] could be seen in the upper and lower side probes. Depending on the discharge conditions, the oscillation times are changed from 2 msec to 10 msec. But always the oscillation occurs just before or in the start of the H-mode. The frequency of this oscillation lies between 2.0 and 3.0 kHz. The mode number m of this oscillation is not clear because of poor arrangement of magnetic probes at that time, but it seems m=2 with the best estimations.

(2) High Frequency Characteristics

Fig. 4 is the contour plots of magnetic probe signal, which represents the high frequency(20.0 kHz - 300.0 kHz) characteristics in OH- and H-mode during 16 msec. When neutral beam is not injected (#81988), there are broad oscillations between 60 kHz and 180 kHz. In the neutral beam injected discharge without H-mode transition, there appears high frequency oscillation around 230 kHz during the heating time. In the H-mode, oscillation amplitude is smaller compared with that of other modes. But spike like broadband oscillations frequently appears during H-mode. There are two sources of short time oscillation in MHD magnetic probes. One is sawtooth and the other is ELM. Usually sawtooth causes low

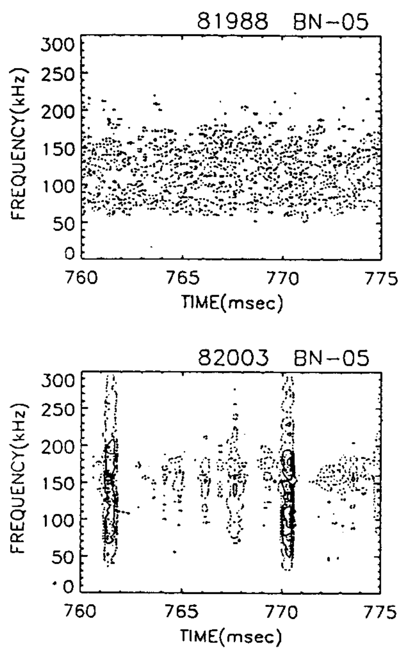

Fig. 4 The contour plots of the MHD probe signals in OH- and H-mode(HF case).

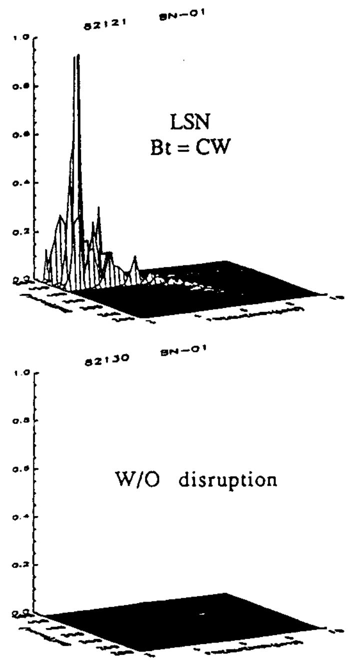

Fig.5 The surface plots of the MHD probe signals in disruptions.

frequency oscillation between 5 kHz and 7 kHz, and ELM causes broadband high frequency oscillation. Also ELM causes H_α peaks, on the other hand sawtooth causes the abrupt increase in the PIN diode signal.

4. Characteristics in Disruptions

Usually disruptions are related with mode locking. When locking is made, MHD oscillations are slowed down or even to stop. Fig. 5 shows the example of the surface plot of magnetic probe signal in the disruption in JFT-2M. The plots were made by FFT analyzation during every 5 msec. It could be seen that all disruptions are related with mode lockings. With time, the oscillation frequency becomes lower and amplitude becomes larger. Sometimes it results in disruption, but sometimes it is unlocked without disruption.

Depending on the operation conditions, different boundary transports are expected. Therefore it is quite possible that different disruption characteristics could be found in different operation conditions. The frequency range between 1.3 kHz and 20 kHz is analysed here. All disruptions are related with n=1.

In JFT-2M, upper and lower divertor have different structures. Upper divertor plate is armored with graphite and lower divertor plate is armored with stainless steel. Fig. 6 shows plasma currents and magnetic probe signals for several disruption shots in USN plasma. Usually m=3 MHD oscillation is the main mode in the plasma current rising phase, but sometimes m=2 oscillation becomes main one. If m=3 mode glows after 400 msec, it results in disruption(Fig. 6(a)). But if m=3 mode glows earlier than 400 msec, the oscillation is unlocked without causing disruption (Fig. 6(b)). It is believed that they are related with q values. But the m=2 mode glows later again. The large oscillation of m=2 near 400 msec doesn't cause disruption in some cases.

LSN plasma is earned with closed divertors made by stainless steel in JFT-2M. LSN plasma looks like more stable for m=3 mode than that of USN from the fact m=3 mode

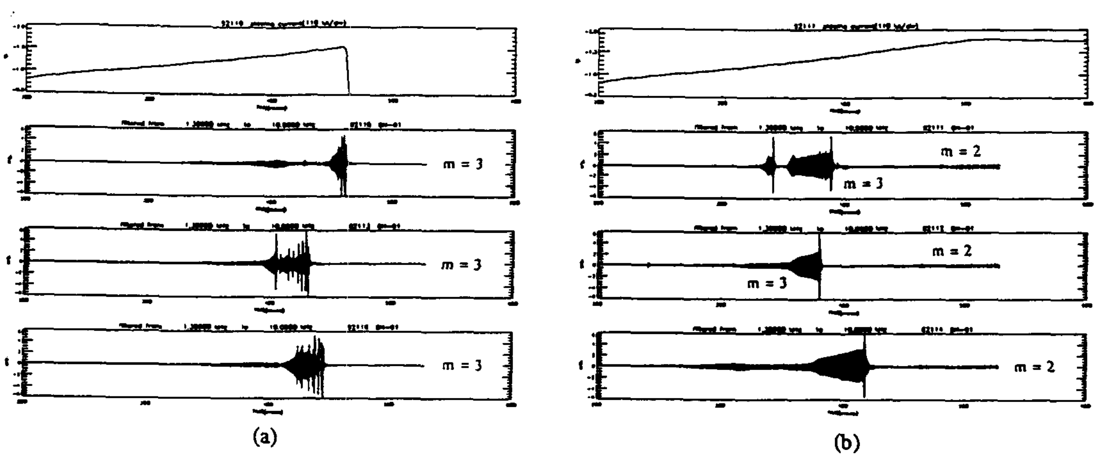

Fig. 6 Time evolution of plasma current and magnetic probe signals in disruptions(USN).

oscillations are not disrupted even though it appears after 400 msec in the LSN plasma. Another possibility is that the direction of toroidal field makes the difference. Also there are clear dependence of the shapes of the probe signals on the direction of the toroidal field. It is supposed that the change of the particle drifts depending on direction of the toroidal field causes some different boundary transports.

5. Results and discussions

Depending on the probe's position and frequency response, different characteristics are observed in the H-mode. Precursor like oscillation around 2.5 kHz, which continues several msec, always occurs just before the start of H-mode. It is cleary seen in the top and bottom side probes. Clear differences between sawtooth and ELM could be found in the magnetic probe signals. The sawtooth always makes the oscillation around 6.0-7.0 kHz in the outer side magnetic probes. But ELM accompanies broadband high frequency oscillation in all poloidal probes. Also it is found that NBI causes high frequency MHD oscillation around 230 kHz in the L-mode.

Depending on the operation conditions, different characteristics of disruption could be found in the magnetic probe signal. Different divertor plate materials contacting the plasma may explain the different behavior of the disruption phenomena occured at the current rising phase. Not only the divertor material, but also the direction of toroidal field make some differences in MHD oscillation. General characteristics of disruption in JFT-2M are;

(1) All disruptions are related with m=2 or m=3 mode oscillations.
(2) n=1(or odd number) in every oscillations.
(3) In the end of every mode locking, there always appears H_α increase.
(4) Small phase changes are seen among the poloidal magnetic probes near the divertors.
(5) No special characteristics could be seen in density shapes.

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