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Study of pressure gradient MHD instabilities in LHD plasmas
ＬＨＤにおける圧力駆動型MHD不安定性の成長率の研究

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The growing behavior of the typical MHD activities in LHD, the rotating and the non-rotating modes, are studied in order to resolve the difference of the influence of the modes on the confinement performance. The growth rates of the rotating and the non-rotating modes, which are the typical MHD activities in the LHD experiments, are studied. The growth rate of the rotating mode is same order with the predicted one. On the contrary, that of the non-rotating mode is much slower than the predicted one.

1. Introduction

In the recent LHD experiments, the high beta with more than 5% as the volume averaged toroidal beta value, <β>, which is relevant to that of a heliotron reactor design, are sustained for a period of ~100 times of the energy confinement time without disruptive phenomena. However, LHD has been considered to have a disadvantage with respect to pressure driven magneto-hydrodynamics (MHD) instabilities because the magnetic hill region exists. In the LHD experiments, some kind of MHD activities are observed. Two among them are typical [1]. One is characterized as the rotating modes, which means that the instability has a real frequency. The modes are observed in the wide regime of the plasma parameters where the interchange instabilities are predicted by the linear MHD stability analysis. And the amplitude of the fluctuation increases with the increase of the beta gradient and the decrease of the magnetic Reynolds number. The effect on the confinement performance is a little. Figure 1 shows a wave form and a beta profile in the typical discharges with the rotating modes of m/n=1/1. Here m and n are the poloidal and troidal mode numbers. In Te profile enclosed by the circles, the fine structures are observed as shown in Fig.1(b). Another typical MHD activity is characterized as the non-rotating mode. The mode

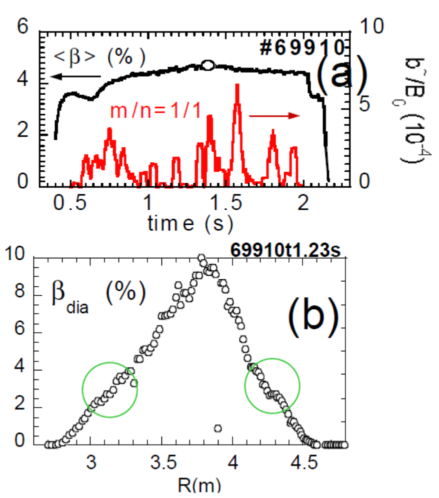

Fig.1 (a) Magnetic fluctuation behavior of low-n mode in a high beta discharge. (b) Pressure profile of the high beta plasmas with the magnetic fluctuation.

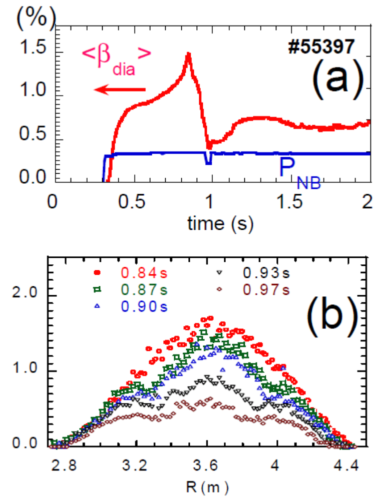

Fig.2 (a) Time evolution of the beta value in the low-magnetic shear and the magnetic hill plasma with a collapse. (b) The time evolution of the electron temperature profile during the colapse.

are observed in the low magnetic shear and the magnetic hill configuration with the relatively low-beta value and the collapse behavior, which means that the core pressure rapidly decreases. Figure 2 shows the wave form and the electron temperature profile in the typical discharges with the non-rotating modes. The averaged beta value and the central temperature decrease by one third due to the collapse.

In this paper, the growing behavior of the MHD activities are studied in order to resolve the difference of the influence of the modes on the confinement performance.

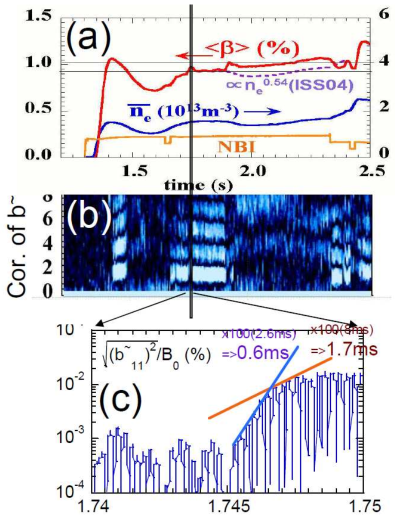

Fig.3 (a) Time evolution of the beta and the line averaged density in a discharge with the appearance/ disappearance of the rotating magnetic fluctuation. (b) Contour of the correlation of the magnetic fluctuation. (c) Time evolution of magnetic fluctuation amplitude of m/n=1/1 mode.

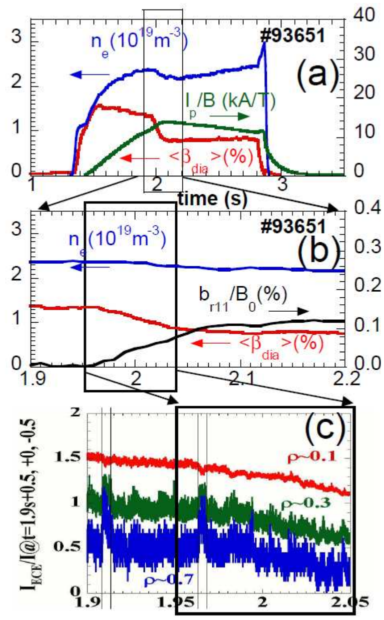

Fig.4 (a) Time evolution of the beta, the toroidal plasma current and the line averaged density in a discharge with a collapse. (b) The detail time evolution of the beta, the non-rotating m/n=1/1 magnetic fluctuation amplitude and the line averaged density. (c) Time evolution of ECE signals for various minor radial location.

2. Time evolution of the fluctuation in the phase of appearance of MHD instabilities

Figure 3 shows the time evolution of the beta, the electron density, the correlation of the magnetic fluctuation in the frequency space and the magnetic fluctuation amplitude of m/n=1/1 mode in a discharge with the appearance/ disappearance of the rotating magnetic fluctuation. In Fig.3(b), the white regions correspond to the frequency of the low-n instabilities, that around 1.5kHz to the m/n=1/1 mode and those around 3kHz, 4.5kHz, 6kHz to the higher harmonics. At t~1.75s, the exited m/n=1/1 mode disappears once and it appears again 20ms later. The growth rate in the first phase is ~1/0.6 [ms^{-1}], changes to ~1/1.7[ms^{-1}] later, and finally the mode amplitude is saturated. According to a linear stability analysis, the growth rate of the resistive interchange mode is predicted ~1/0.1[ms^{-1}], which is same order to that in the initial phase of the instability growth.

Figure 4 shows the time evolution of the beta, the density, the non-rotating magnetic fluctuation amplitude and ECE signals in a discharge with the non-rotating mode. The growth rate of the non-rotating mode is ~1/100 [ms^{-1}], which is much slower than the predicted one. Any precursors has not been found yet. In Fig.4(c), the ECE signals are shown in the just after the instability occurs. Some burst signals with the rapid growth rate ~0.1 [ms] is found. The 0.1 ms is almost same with the predicted linear growth rate.

3. Summary and discussion

The growth rates of the rotating and the non-rotating modes, which are typical MHD activities in the LHD experiments, are studied. The growth rate of the rotating mode is same order with the predicted one. On the contrary, the non-rotating mode much slowly grows than the predicted one.

In an early papers, the strong relation between the influence of the confinement and the mode width was suggested [2]. However, the growth rate might be another main player of the confinement influence. To resolve it is one of our future subject.

Reference

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