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Analysis of the sawtooth-like oscillations observed in the core region of the LHD using equilibrium by HINT-2

HINT-2による平衡磁場を用いた接線像の逆変換手法による LHDコア部の鋸歯状振動の解析

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In the Large Helical Device (LHD), sawtooth-like repetitive relaxation phenomena are observed when the pressure gradient is increased by pellet injection. When the mode is localized in the core, m/n = 3/1 type precursors are clearly observed. Reconstruction of the line-integrated soft X-ray image is investigated to study the evolution of the pressure driven MHD activities. Using an assumption that radiation is constant along the magnetic, the tangential viewing lines are projected onto a poloidal cross section based on the estimated magnetic field by HINT-2 code. Reconstruction of the mode structure of the pre-cursor oscillations is tried.

1. Introduction

Since there is no net-current in Heliotron devices, to study the effect on the confinement of the pressure driven modes is important to achieve high-beta plasmas in the Large Helical Device. The stability of the pressure driven modes, e.g., the interchange mode depends on the depth of the magnetic well; the location of the magnetic axis, by which the well depth is affected, should be carefully controlled.

From the viewpoint of the confinement, inward-shifted configurations, e.g. magnetic axis Rax = 3.6m is better for getting good performance. However, whole plasma are in the magnetic hill in the vacuum magnetic field and most part of the plasma remains in the hill region with the increase of the beta. That is to say we are operating the LHD mainly with an unstable condition of the interchange mode. Therefore, it is very important to study how these unstable modes behave while the beta increases. So far, we are observing a three kind of phenomena when the amplitude of the MHD activities evolves. 1) Coherent oscillations, 2) Saturation of non-rotating mode at rational surfaces. 3) Sawtooth-like repetitive oscillations at rational surfaces [1]. q = 2 (m/n = 2/1) type, q = 1 (m/n = 1/1) type are commonly observed in LHD. In this study, these kind of sawtooth-like oscillations are mainly discussed.

2. Experiment

Fairly high-density plasmas (line averaged electron density $n_e > 10^{20}$ m^{-3}) are produced by the sequentially injected hydrogen ice pellets. Sawtooth-like oscillations are observed in this type of discharges when the magnetic axis is inward shifted (Rax = 3.55m, 3.6m and 3.65m). While the electron density decreases the profile shape becomes gradually peaked. Together with the peaking of the electron temperature, the pressure gradient increases and is 2 ~ 3 times larger than the gradient found in normal operation with gas fueling.

As the pressure gradient increases, sawtooth-like events begin at several rational surfaces, e.g, 1/q = 1/1, 1/2 and 1/3. Note that, q profile in LHD is a decreasing function where q ~ 3 is located in the core and q ~ 3/2 in the edge region. Here, we discussed the q = 3 (m/n = 3/1) type sawtooth (core localized) since the clear pre-cursor like oscillations are observed; it is a good example for studying the non-linear evolution of the pressure driven mode.

Fig.1 shows the fluctuating components of the line-integrated image from the tangential viewing soft x-ray camera at the time of the maximum fluctuation amplitude. First, an m=3 mode evolves within 100 ms and deforms the magnetic surface (Fig. 1 (B2) bright area). This m=3 triangular structure expands and reaches the region around ρ=0.4, an enhanced heat flux from the core to the edge is observed, thereby causing a flattening of the pressure profile.

3. Reconstruction of the line-integrated image

Though line-integrated images give a rough image of the phenomena, tomographic reconstruction might be useful to study the exact structure pre-cursor and the nature of the collapse events.

Reconstruction assuming the constant emission along the magnetic field lines has been tried [2]. In this method, tangential viewing lines are projected on a poloidal plane as curved lines (see, Fig. 2) and 2D reconstruction method is performed. In the projection process, tracing of the magnetic field lines is required. Magnetic field was estimated using a VMEC [3] based equilibrium. However, the density of the flux surfaces in the VMEC coordinate in the core region is not enough. It is not possible for the reconstruction of the core-localized modes, such as m/n =3/1 sawteeth.

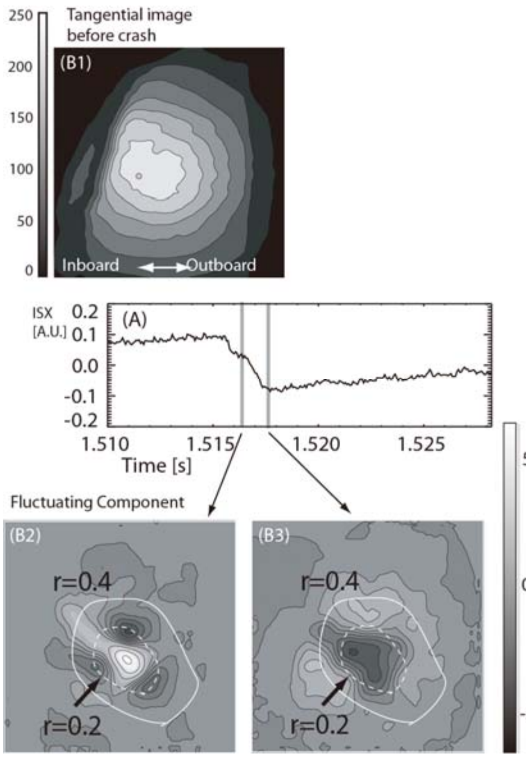

Fig.1. Line integrated tangential image of a sawtooth-like crash. Fluctuation components are shown in (B2) and (B3)

We have developed [4] new method for the estimation of the magnetic field line using HINT-2 equilibrium [5, 6]. Since the magnetic field can calculated in the regular grid location, we can trace the magnetic field line even near the magnetic axis. The reconstruction of the mode structure based on this technique and the characteristics of the relaxation phenomena in LHD will be given in the presentations.

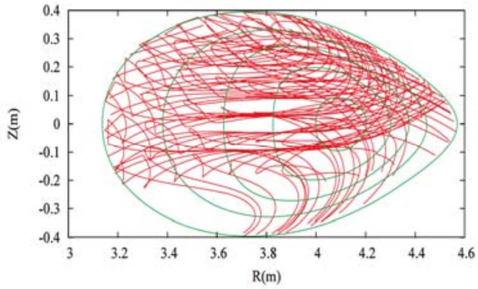

Fig.2 A sample of the projection of the magnetic field lines on a poloidal plane. (Fig.2 of Ref [4])

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