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Magnetic Diagnostics of Non-Rotating Magnetic Island in LHD

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1.Introduction

Magnetic islands sometimes play key roles in toroidal plasma confinement from the viewpoint of Magneto-Hydro Dynamics (MHD) stability. In Tokamaks, for example, a seed island triggers a neoclassical tearing mode, and its growth leads to serious deterioration of the confinement. On the other hand, it is possible that the island flattens the pressure profile at the resonance surface, contributing to the stabilization of the pressure-driven resonant MHD mode. In the Large Helical Device (LHD), the perturbed field $\tilde{b}_0$ produced by the external perturbed coils [1] can produce a magnetic island in the vacuum field. The seed island grows or reduces without rotation during the plasma discharge. The width, w, of the island is indicated by the flattening of the electron temperature profile measured by Thomson scattering. In LHD the profile only can be obtained at one toroidal position and therefore gives limited knowledge of the structure of the island.

The width w is related to the perturbed field [2]

$$w^2=C(\tilde{b}_0+\tilde{b}_1)/B_t \qquad (1)$$

here C, $\tilde{b}_1$ and B_t are a constant, perturbed field during the plasma discharge and the toroidal field, respectively. For $\tilde{b}_1=0$ and $\tilde{b}_0\neq0$, the width w is equal to that of the vacuum island ($w=w_{vac}$). The magnetic diagnostics measuring the profile of $\tilde{b}_1$ is an effective method to find the structure of the magnetic island.

2.Experimental setup

The toroidal array of magnetic flux loops is set at the outer ports in LHD as shown in Fig.1. Each flux loop has N=10 turns wound at the ports whose cross-sections are around $S\approx1.2\text{m}^2$ and have a total cross-section of about NS=12m^2,which leads to enough electromotive force voltage to detect the slow (few 100ms) and weak (few Gauss) change of the magnetic field.

The shapes of the flux loops at the toroidal angles $\phi=-162, -54, 54, 90$, and 162 are planar (coloured line in Fig.1) that we use here and the other ones are 3-dimensinal (dotted line in Fig.1). During a plasma discharge these loops can detect the perturbed magnetic flux Φ^{R} which originates from the growth and reduction of the width of the island. The detected magnetic fluxes Φ^{R}s are normalized by the total cross section NS to $\tilde{b}_1$ whose component is in the major radial direction. The 4-pairs of perturbation coils placed at the top and bottom of LHD around $\phi=\pm 90$[deg] (solid line in Fig.1) produce the static perturbation field $\tilde{b}_0$ having an $m/n=1/1$ mode which produces a seed island whose O(X)-point stays at the outer board side at $\phi=90(-90)$[deg] in this study. A Thomson scattering system measures the T_e profile at $\phi=-18$[deg]. The w is estimated as the inner flattening width of the T_e profile as shown in Fig3(a)(c).

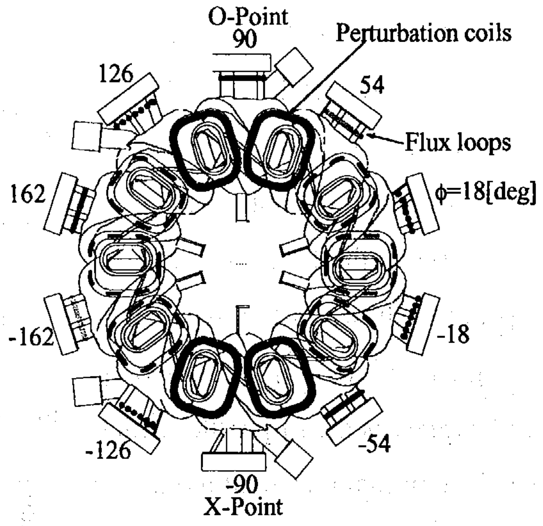

Fig.1 Top view of the vacuum vessel of LHD Toroidal angle ϕ is defined $-180<\phi<180$[deg]

3. Experimental results and discussion

The typical discharge with a seed island ($w_{vac}\approx 150$[mm]) produced by the perturbed field $\tilde{b}_0$ is shown in Fig.2, in which the island width w grows from 150 to 200[mm] as shown in Fig.2(d). The magnetic field $\tilde{b}_1$ varies with time (Fig.2 (e)). Each colour corresponds to that of the flux loops in Fig.1. The $\tilde{b}_1$ at $\phi=-162$ and 162[deg] reduces to $\tilde{b}_1\approx -0.8$[Gauss]. On the other hand, the $\tilde{b}_1$ at $\phi=54$[deg] increases to $\tilde{b}_1\approx 0.8$[Gauss].

The T_e and $\tilde{b}_1$ profiles at $t=0.48$ and 1.73[s] are shown in Fig.3. At $t=0.48$[s], Fig3(a) shows that the island width does

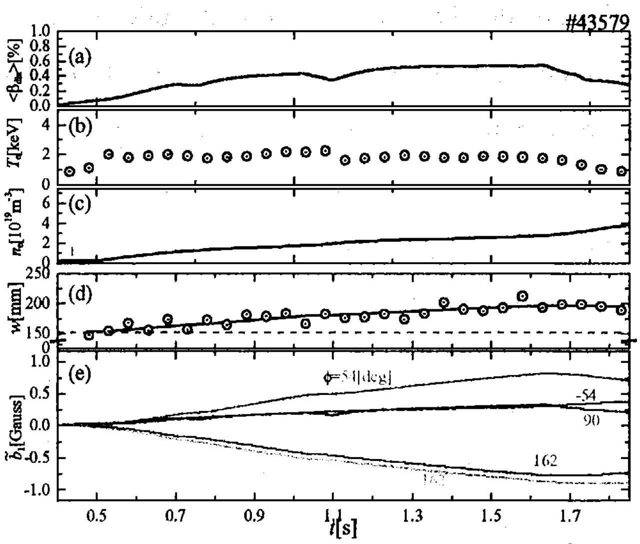

Fig.2 Time evolution of (a)averaged beta $<\beta>_{dia}$ (b)electron temperature at centre T_e (c)averaged electron density n_e (d)island width w (e)perturbed field $\tilde{b}_1$

not change and is almost same as the seed island width. The flux loops detect zero field $\tilde{b}_1$ as shown in Fig3(b). At t=1.73[s], the island width becomes w=200[mm] (Fig3(c)) and the finite field $\tilde{b}_1$ appears as shown in Fig3(d). The fitting curve $\tilde{b}_1(\phi)=\tilde{b}_1^{\,n=1}\cos(\phi-\phi_{n=1})$ well expresses the $\tilde{b}_1$ profile, which has the dominant toroidal mode n=1. Here, $\tilde{b}_1^{\,n=1}$ and $\phi_{n=1}$ are the maximum amplitude and its toroidal angle respectively. Figure4 shows the time trace of the $\tilde{b}_1^{\,n=1}$ and $\phi_{n=1}$. The amplitude increases from $\tilde{b}_1^{\,n=1}$=0 to 0.9[Gauss] (Fig.4(a)) and the angle does not change from around $\phi_{n=1}$=0 during the plasma discharge(Fig.4(b)). These results mean that the magnetic island width increases with time and does not rotate, and the position of O(X)-point stays at inner (outer) board side at $\phi=-90$[deg].

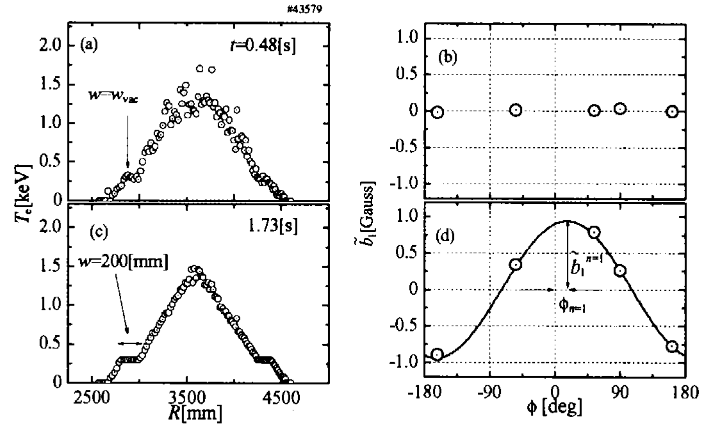

Fig.3 T_e and $\tilde{b}_1$ profile at (a)(b) t=0.48[s], (c)(d) 1.73[s]

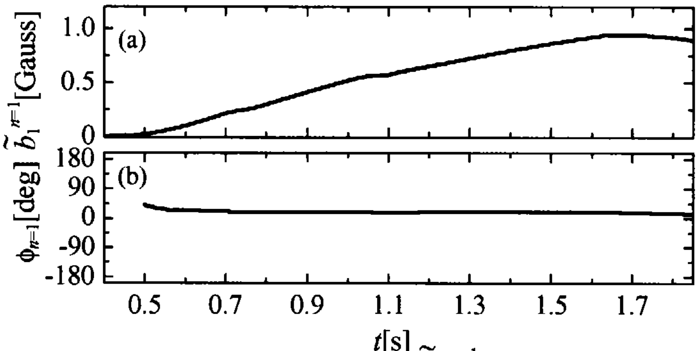

Fig.4 Time trace of (a) $\tilde{b}_1^{\,n=1}$ and (b) $\phi_{n=1}$

The profile of $\tilde{b}_1$ with the toroidal mode n=1 indicates that the change of the magnetic island width during a discharge also has the n=1 mode component. These results depend on the assumption that the profile of $\tilde{b}_1$ is due to the structure of the island with the m/n=1/1 component. The amplitude $\tilde{b}_1^{\,n=1}$ estimates the width w by using Eq (1) that can be rewritten as follows

$$w=(\alpha(\tilde{b}_1^{\,n=1}/B_t)+w_{vac}^{\,2})^{0.5} \qquad (2)$$

The calibration between w and $\tilde{b}_1^{\,n=1}/B_t$ provides the coefficient α for the island enlargement cases ($w \geqq w_{vac}$). As a result, the magnetic diagnostics can estimate the island

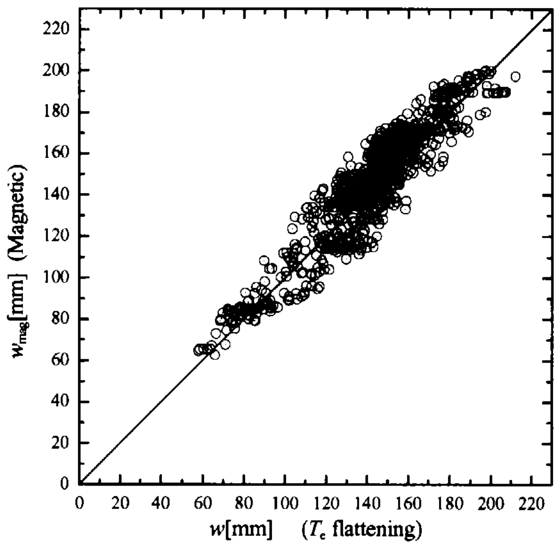

Fig.5 Relationship between w_{mag} and w

width w_{mag}. Figure5 shows the relationship between w and w_{mag}. The solid line in Fig2(d) is the time trace of w_{mag} derived from $\tilde{b}_l$, which can fit the w. These results show that this magnetic loop with large NS can be used to estimate the structure of the non-rotating magnetic island.

For the island reduction or disappearance ($0<w< w_{vac}$, in other words, healing [3,4]), finite $\tilde{b}_l$ can be detected even though a seed island exists. Figure 6 shows the T_e and $\tilde{b}_l$ profiles for the island disappearance case with w_{vac}=114[mm]. The flattening does not appear (Fig6(a)) and finite $\tilde{b}_l^{n=1}$ is indicated and $\phi_{n=1}$ shifts by 180[deg] from the increasing case shown in Fig3(d).

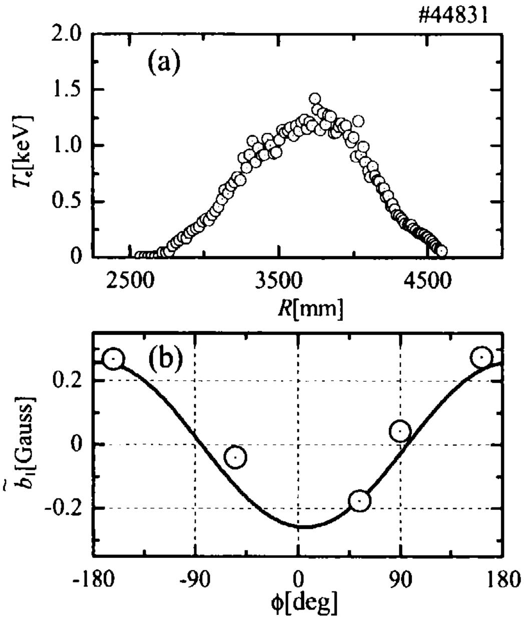

Fig.6 T_e and $\tilde{b}_l$ profile for the island reduction plasma

This result means that some kinds of current layer inside plasma produce $\tilde{b}_l$ that suppresses the seed island in the LHD. We are studying what kind of structure the current layer has.

4. Summary

We carry out the magnetic diagnostics of non-rotational magnetic island in LHD. The finite magnetic field appears with a change of the magnetic island width. Magnetic diagnostics can estimate the structure of an island. Even in the disappearance of a magnetic island, a finite magnetic field appears. Further study is intended to reveal the formation mechanism of the current layer producing $\tilde{b}_l$ which affects the behaviour of the magnetic island.

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References

[1] T. Morisaki et al., Fusion Engineering and Design. **65**, 475 (2003)

[2] A. H. Boozer, Phys. Fluids **27**, 2055 (1984)

[3] K. Narihara et al., Physical Review Letter **87**, 135002 (2001)

[4] N. Ohyabu et al., Physical Review Letter **88**, 055005 (2002)