23P070-P

Experimental Investigation of Influence of Externally Applied Resonance Magnetic Perturbation on Magnetic Structure during Tokamak Disruption.

外部共鳴摂動磁場印加がディスラプション時の磁場構造へ与える影響の実験的検証

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Tokamak disruptions are one of the most critical issues for the ITER and demo-reactors, because an intense heat load on plasma facing components and large electromagnetic forces on the vacuum vessel and in-vessel components are generated during the disruption. Therefore, the disruption control technology is necessary for the fusion tokamak devices, and many studies have been carried out until now. In this study, we investigated the effect of externally applied resonance magnetic perturbation on the disruption control in the small tokamak device HYBTOK-II.

1. Introduction

The tokamak disruption, which is accompanied by an intense heat load on plasma facing compornents during thermal quench and a large electromagnetic force on in-vessel components during current quench, is one of the most crucial issues for next generation tokamak devices such as ITER [1]. Disruption control and avoidance are necessary from the viewpoints of device protection, and many studies have been done in many tokamak devices [1]. In HYBTOK-II, which is a small tokamak device in Nagoya Univ., the disruption experiment had been carried out to understand the occurrence mechanism of disruption [2]. In Ref. 2, a growth of m / n = 3 /2 tearing mode, where m and n are poloidal number and toloidal number respectively, was observed just before the disruption. And then, a rapid change of sudden pump-out of the core plasma current, which was induced and shifted the plasma center position to vacuum vessel inner side, has been observed. The critical issues in the tokamak disruption such as heat load have been investigated in many devices [3,4]. An example is a study on a resonance magnetic perturbation (RMP) applied to tokamak plasma. RMP can generate the ergodic magnetic region in the plasma egde region [5]. Therefore RMP can change the plasma current density distribution drastically during the disruption. In this study, we investigated the effect of externally RMP on the plasma current density distribution during the disruption in order to control the disruption.

2. Waveform of disruption in HYBTOK-II

HYBTOK-II is a small tokamak device with a limiter configuration. The major radius R is 40 cm, and the minor radius of the vacuum vessel and the limiter radius a are 12.8 and 11 cm, respectively [6]. Hydrogen is used as the working gas in the experiments and the discharge duration is 20 ms. The RMP coils are composed of two sets of local helical coils, which have an IGBT invertor power supply [7]. The RMP coils are installed outside the vacuum vessel and poloidal and toroidal numbers of

RMP coils are m = 6 and n = 1, respectively. The maximum coil current in RMP system is 150 A, and the frequency changed from 1 to 30 kHz.

The typical waveform of disruption discharge in HYBTOK-II is shown in Fig. 1. Disruption was driven by ramping up the plasma current, I_p, to reduce the plasma surface safety factor, q_a. In the experiment, the positive spike of plasma current appeared at $q_a < 3$, and then a negative spike of the plasma loop voltage V_{loop} and an inward shift of the plasma column were observed.

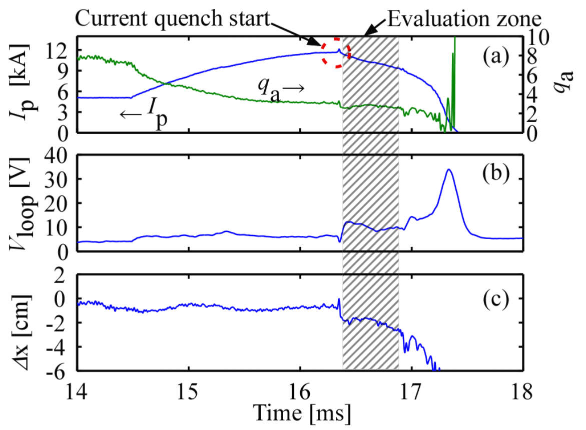

Fig. 1. Time evolution of (a) plasma current I_p, and plasma safety factor q_a (b) plasma loop voltage V_{loop}, and (c) the distance from horizontal plasma current centre Δx.

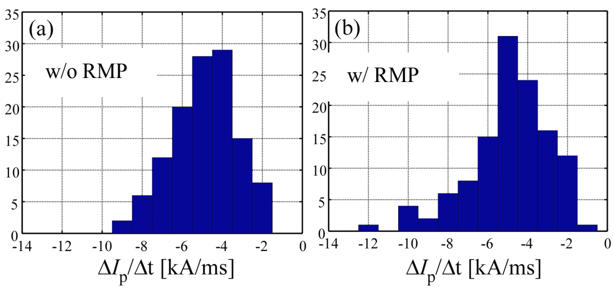

Fig. 2. Histogram of the plasma current decay rate, $\Delta I_p/\Delta t$, (a) without RMP and (b) with RMP

The analytic interval in this study corresponds a hatched area in Fig.1 because the plasma center and plasma cross-section didn't change in this region. The current decay rate, $\Delta I_p/\Delta t$, was evaluated by linear approximation of plasma current in an analytic interval. The RMP was applied from t = 13 to 20 ms.

3. Experimental result

Figure 2 (a) and (b) show the histogram of the plasma current decay rate, $\Delta I_p/\Delta t$, without RMP and with RMP during disruption. The number of shot is 120 in Fig. 2 (a) and (b), respectively. The average value of plasma current decay rate, $\Delta I_p/\Delta t$, in Fig 2 (a) is -4.98 kA/ms, while the average value of that in Fig. 2 (b) is -4.43 kA/ms. However the effect of RMP on the current density distribution during the disruption was observed in this study.

4. Discussion and Summary

We investigated the influence of RMP on the current decay during disruption in the HYBTOK-II. However, we couldn't obtain the significant effect of RMP for the disruption.

In order to understand the reason why RMP did not act on the current decay during the disruption, we argued over the penetration time of RMP. The diffusion of magnetic field is determined by the resistive diffusion time τ_R,

$$\tau_R = \mu_0 L^2 / \eta \,, \tag{1}$$

where μ_0 is the permeability of vacuum and L is a half of the plasma limiter radius, which is 0.055 m because the magnetic islands exist in HYBTOK-II. The plasma resistivity η is calculated using the classical Spitzer formula [8]. If the effective charge Z_{eff} is assumed to be1, the plasma resistivity η ~ **7.1** $\times 10^{-4}$ $T_e^{-3/2}$ [Ωm]. In the current quench phase, the electron temperature, T_e, in the region where the magnetic islands exist is 30~50 eV. Therefore, the resistive diffusion time τ_R is 0.6~1.9 ms. Because the RMP coil current frequency was 1~30 kHz, the plasma couldn't respond against the RMP.

For the future, we are planning to use the direct current power supply for RMP coils due to reduce the skin effect of vacuum vessel, and continue to investigate the influence of RMP on the current decay during the disruption.

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