18PB-023

Influence of MHD instability just before disruption on the electron temperature profile after the thermal quench in JT-60U

JT-60Uにおけるディスラプション直前のMHD不安定性が熱クエンチ後の電子温度分布に与える影響

Yoshihide Shibata[1)], Go Matsunaga[1)], Satoru Sakakibara[2)], Yasunori Kawano[1)]
Akihiko Isayama[1)] and Kiyomasa Watanabe[1), 2)]
柴田欣秀，松永剛，榊原悟，河野康則，諫山明彦，渡邊清政

[1)] *Japan Atomic Energy Agency, 801-1, Mukouyama, Naka, Ibaraki 311-0193, Japan*
[2)] *National Institute for Fusion Science, 322-6, Oroshi-cho, Toki, Gifu 509-5292, Japan*
[1)] 日本原子力研究開発機構　〒311-0193　茨城県那珂市向山
[2)] 核融合科学研究所　〒509-5292　岐阜県土岐市下石町322-6

To investigate the influence of MHD instability just before the thermal quench (TQ) on the electron temperature T_e profile just after the TQ, we analyzed disruption discharges induced by neon massive gas-puff. The T_e profile just after the TQ in low safety factor at the plasma surface q_{surf} discharges was became more peaked profile than those in high q_{surf} discharges. The ratio of peaking factors of current density j and T_e profiles, ν_{Te}/ν_j, just after the TQ, which represents the plasma current diffusivity into core plasma, in low q_{surf} discharges is higher than in high q_{surf} discharges.

1. Introduction

Disruption in a tokamak device is one of the most critical issues for the ITER and DEMO reactors [1]. Because disruption releases all thermal and magnetic energy in a brief period, it leads to the generation of high heat loads on the plasma-facing components (PFCs) and large electromagnetic forces in the vacuum vessel and in-vessel components. It can cause serious damage to these components, and it is necessary to avoid or mitigate disruption.

For the development of a disruption mitigation method, Massive Gas Injection (MGI) experiment has been carried out in many tokamak devices [1]. In the massive neon gas-puff experiment in JT-60U, it was reported that the plasma current decay time during the initial phase of the current quench (CQ) depended on increase in the internal inductance l_i [2]. Moreover, it was found from comparison with the simulation results that the electron temperature T_e profile was important for increasing l_i during the CQ [3]. However, determination mechanism of the T_e profile during the CQ has not been understood yet. In this study, we investigate the effect of MHD instability just before the TQ on the T_e profile during the disruption since the TQ was caused by the MHD instability just before the TQ.

2. Experiment

Massive neon gas-puff experiments were carried out to measure the plasma parameters during the disruption in JT-60U [3]. The following typical parameters were set just before the disruption: the plasma current I_p was 0.7-1.4 MA, the toroidal magnetic field strength B_t was 2.3–3.7 T, and the safety factor at the plasma surface q_{surf} was 6.1–10. The major radius R_0 and plasma volume V_p were maintained at almost constant values of R_0 ~ 3.3 m and V_p ~ 61 m^3, respectively. In this study, all discharge analyzed is ohmic heating discharge.

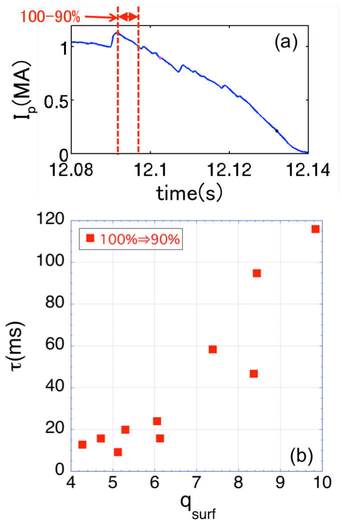

Figure1. (a) Typical waveform of the plasma current during the disruption induced by the massive neon gas-puff in JT-60U and (b) relationship between the experimental current decay time, τ, and the safety factor at the plasma surface q_{surf} just before the thermal quench.

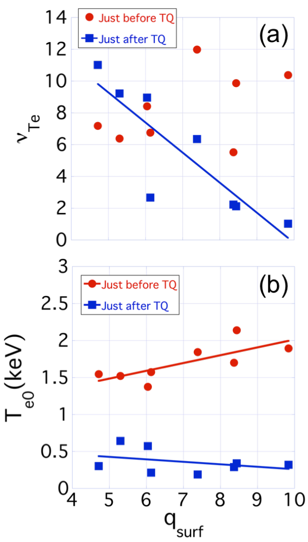

Figure2. (a) Relationships between q_{surf} and the peak index of T_e profile just after the thermal quench, and (b) the time evolution of T_e in the plasma center.

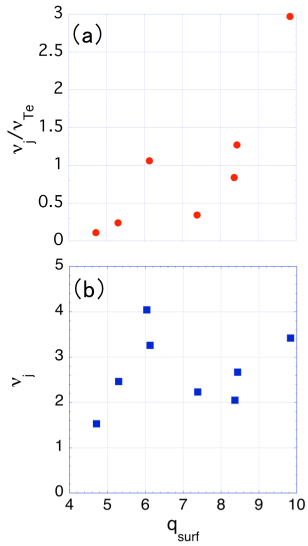

Figure3. Comparison between q_{surf} and (a) the ratio of the peaking factors of the current density and electron temperature profiles and (b) the peaking factor of the current density just after the thermal quench.

3. Results

Figure 1 shows a relationship between the experimental current decay time, τ, and q_{surf} just before the TQ. In these discharges, the current decay time during the initial phase of the CQ (100 - 90%) varies with increase in q_{surf}. Figure 2 shows the peaking factor of the T_e profile ν_{Te} just before and after the TQ and the time change of the T_e in the plasma center. In this study, the T_e profile was measured by Electron Cyclotron Emission (ECE) measurement, and ν_{Te} was fitted by the following equation:

$$T_e(\rho) = T_{e0}(1-\rho^2)^{\nu_{Te}} + 0.01. \quad (T_e \text{ in keV})$$

In these discharges, ν_{Te} just after the TQ was decreased with increase in q_{surf} as shown in Fig. 2 (a). Moreover, the value of T_e in the plasma center just after the TQ was almost same as shown in Fig. 2 (b).

Figure 3 shows a relationship between q_{surf} just before the TQ and the ratio of peaking factors of current density j and T_e profile, ν_{Te}/ν_j, just after the TQ. The peaking factor of j profile was calculated by the following equation [4].

$$\nu_j = \left(\exp(l_i) - 1.65\right)/0.89.$$

In this study, l_i was evaluated by the equilibrium calculation code CCS [5]. As shown in Fig. 3, ν_{Te}/ν_j just after the TQ becomes smaller as q_{surf} just before the TQ is low. The peaking factor of the j profile ν_j just after the TQ was scattered in these discharges. If the T_e profile is more peaked than the j profile, it is easy to diffuse the plasma current into the plasma center. Thus, the ratio of peaking factor ν_{Te}/ν_j represents the plasma current diffusivity into plasma center. From Fig. 3, the plasma current diffusivity into core plasma in low q_{surf} discharges is higher than in high q_{surf} discharges. From these results, the T_e profile just after the TQ is a key parameter to determine the increase in l_i during the initial phase of CQ, and MHD instability that is caused the TQ might affect on the determination mechanism of the T_e profile just after the TQ.

4. Summary

To investigate the influence of MHD instability just before the TQ on the T_e profile just after the TQ, we analyzed disruption discharges induced by neon massive gas-puff. The T_e profile just after the TQ in low q_{surf} discharges was became more peaked profile than those in high q_{surf} discharges, and the ratio of peaking factors of current density j and T_e profile, ν_{Te}/ν_j, just after TQ, which represents the plasma current diffusivity into core plasma, in low q_{surf} discharges is higher than in high q_{surf} discharges. The plasma current decay during the initial phase of the CQ could be affected by the MHD instability just before the TQ because the current decay time during the initial phase of the CQ varies with increase in q_{surf}. As the next study, we are now carrying out detailed MHD instability analysis just before the TQ on different q_{surf} discharges.

References

[1] T. C. Hender, J.C. Wesley, J. Bialek, A. Bonderson, *et. al.*, Nucl. Fusion **47** (2007) S128.
[2] Y. Shibata, K.Y. Watanabe, M. Okamoto, N. Ohno, A. Isayama, *et. al.*, Nucl. Fusion **50** (2010) 025015.
[3] Y. Shibata, A. Isayama, S. Miyamoto, *et. al.*, Plasma Phys. Control. Fusion **56** (2014) 045008.
[4] J. Wesson, Tokamaks 3rd edition, oxford science publications, P. 120.
[5] K. Kurihara, Fusion Eng. Des. **51-52** (2000) 1049.