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Analysis of Current Quench of the JT-60U tokamak by using two dimensional MHD equilibrium calculation Code (DINA).

2次元軸対称MHD平衡計算コードDINAを用いたJT-60Uにおける電流クエンチ解析

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During the disruption of tokamak, the plasma current rapidly decays to zero and it gives the large mechanical force in the structure. In this study, we predicted the time evolution of plasma current during the disruption by using the disruption simulation code, which is called DINA, and investigated the effects of electron temperature, T_e and an effective charge, Z_{eff} on the predicted time evolution of plasma current, I_p in JT-60U radiative disruption. In the calculation, it was found that time evolution of I_p is good agreement with the experimental behavior of I_p when we assumed T_e=30eV and Z_{eff}=3. However, internal inductance, which indicates the shape of current density distribution, evaluated by DINA code differs from the experimental values. Hence, we need to match the experimental and calculated results in order to predict correctly the plasma behavior during the disruption.

1. Introduction

The plasma current and cross-section plasma rapidly decay to zero during tokamak disruption. They generate a halo current and an eddy current, and such currents give a large mechanical force into the structure around the plasma. It is a significant problem for stable operation of fusion tokamak device such as ITER.

In this study, we simulate the behavior of the plasma current during the radiative disruptive discharge in JT-60U by using a disruptive simulation code, DINA in order to clarify the determination mechanism of plasma current decay during the current quench [1].

2. Modification of DINA

DINA is two dimensional MHD equilibrium calculation code for disruption simulation. The rate of plasma current quench in DINA, taking the time evolution of the poloidal flux into account, is determined with specified values of electron temperature, T_e, and an effective charge, Z_{eff} [2,3]. T_e and Z_{eff} are calculated by a Power Balance equation. However, the upper limit of T_e calculation result sets to 10eV because T_e has the single unique solution. To investigate the effect of those plasma parameters on the time evolution of plasma current during disruption, we analyze in the radiative disruptive disruption of JT-60U. Table I shows the assumption values of T_e and Z_{eff} in this calculation [4]. In case A, the T_e and the Z_{eff} were calculated by DINA code. In case B, we assumed T_e equals 20eV and Z_{eff} calculated from Power Balance equation. In case C, we assumed Z_{eff} equals 3.

Table I. The assumption values of T_e and Z_{eff} in this calculation

	T_e (eV)	Z_{eff}
Case A	–	–
Case B	20(constant)	–
Case C	20(constant)	3
Case D	30(constant)	3

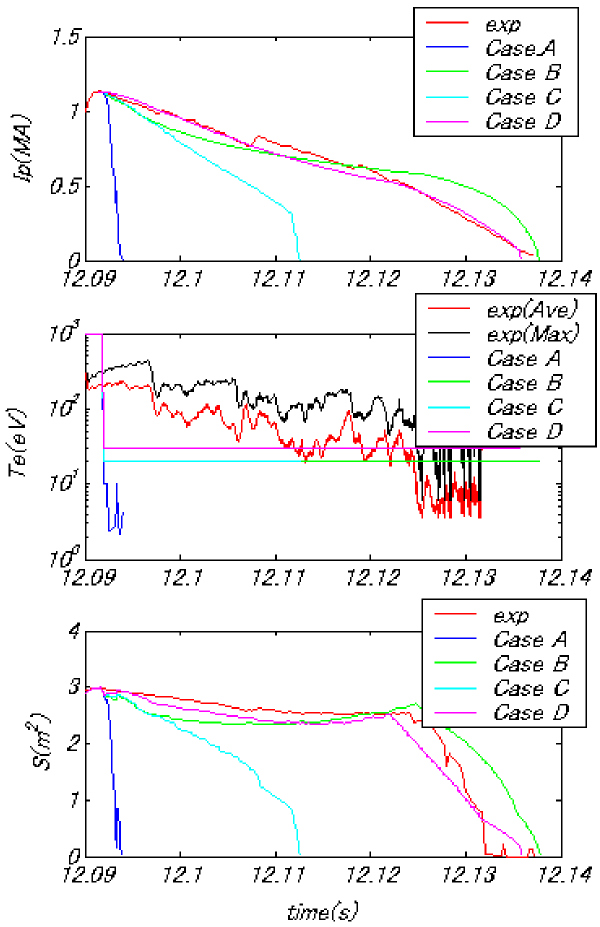

Fig.1.Time evolutions of plasma current I_p ,electron temperature T_e ,and plasma cross-section S

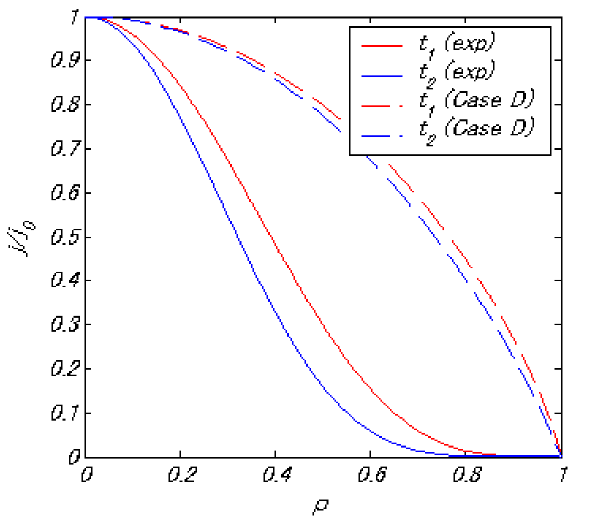

Fig.2. Profiles of normalized current density distribution

3. Result

Waveforms of time evolutions of plasma current I_p, T_e, and plasma cross-section, S, are shown in Fig.1. In case A, DINA does not reproduce behavior of the plasma current, because T_e decays rapidly compared with the experimental data. In case D, time evolutions of the I_p and S were good agreement with the experimental data.

Fig.2 shows profiles of normalized current density distributions at $I_p = I_{p0}$ (t_1) and $I_p = 0.9 \times I_{p0}$ (t_2). Here I_{p0} is the value of plasma current just after current quench starts. ρ is a normalized plasma small radius. The current density profile is calculated by the Eq(1)

$$j/j_0 = (1-\rho^2)^{\nu}, \qquad (1)$$

$$\nu = (e^{l_i} - 1.65)/0.89, \qquad (2)$$

where ν is the peaking factor and l_i is the internal inductance [3]. In experimental data, we calculated ν using the Eq(2). When $I_p = I_{p0}$, in case D, this profile does not match the experimental measurement. Furthermore, time change of experimental current density profile is peaking at center relative to time change of DINA.

In addition to, in case C, I_p decays more rapidly relative to case B and in case B, averaged Z_{eff} is 1.29. Therefore, the rate of plasma current quench depends on Z_{eff}.

4. Summary

We analyzed the current quench in the radiative disruption of JT-60U by using DINA. When we assumed T_e=30eV and Z_{eff}=3 in DINA, we showed the behavior of the plasma current is good agreement and Z_{eff} affects to I_p. However, DINA profile of normalized current density distribution at $I_p = I_{p0}$ does not match the experimental measurement, because flat T_e profile was assumed in the present DINA calculation.

For future work, we will introduce the measured T_e profile to the DINA code to reproduce the profile of the normalized current density distribution more accurately.

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