§49. Study of Decay Time during Plasma Current Ramp-down in LHD Plasma

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The study's purpose is to clarify the relation between the plasma parameter and the current decay time during ramp-down of the plasma current in the toroidal magnetic confinement device. In tokamak devices such as ITER, the plasma is confined by the magnetic field generated due to the plasma current as well as the external magnetic field coils. Therefore, understanding of quench of the plasma current, such as disruption, has been one of the most critical issues in the tokamaks. In the helical devices, the confinement of plasma can be sustained without the plasma current because the helical device always keeps magnetic surfaces externally. However, the unexpected plasma current generated by such as unbalanced Neutral Beam (NB) injection and bootstrap current have an influence on the plasma operation[1]. For example, over 100 kA of plasma current was observed by unbalanced NB injection in LHD device[2]. Therefore, the control of the plasma current is also important in helical devices.

In this paper, we focus on the plasma current decay at the end of the normal plasma discharges in helical devices. Figure 1 shows the end of the plasma current waveform and the temporal evolution of the plasma inductance and resistance estimated by the experimental data in LHD plasma. The plasma current is driven by unbalanced NB injection and NB injection is turned off at t = 3.34 sec. Then, the waveform of plasma current has the slow and rapid decay. The plasma inductance and resistance is estimated by the profile of plasma resistivity. The profile is evaluated by the electron temperature profile measured by Thomson scattering system.

We use the following circuit equation in order to decide the current decay time.

$$R_p L_p + \frac{dL_p}{dt} I_p = V_{ex} - L_p \frac{dI_p}{dt} \qquad (1)$$

where R_p and L_p are the plasma resistance and inductance, respectively. The right-hand side of eq. (1) is corresponding to the loop voltage of plasma surface. From fig. 1, it is found that the time derivative of the plasma inductance is small and the plasma resistance changes significantly in slow decay of the plasma current. Therefore, the value of the left-hand side of eq. (1) is mainly dependent on the plasma resistance.

Figure 2 shows the waveform of plasma current and the temporal evolution of the electron temperature profile measured by electron cyclotron emission diagnostic system during plasma current ramp-down. In the rapid decay of the plasma current, the electron temperature cannot be measured because it is too low. In fig. 2, it is found that the electron temperature sequentially decreases from edge to core region before the rapid decay occurs. So, the plasma column is shrunk and it is thought that plasma resistance becomes very large just before the rapid decay phase. Therefore, the plasma current ramp-down is occurred by the increment of plasma resistance and it is thought that the decay time of plasma current is mainly determined the plasma resistance during slow and rapid decay phase in LHD plasma.

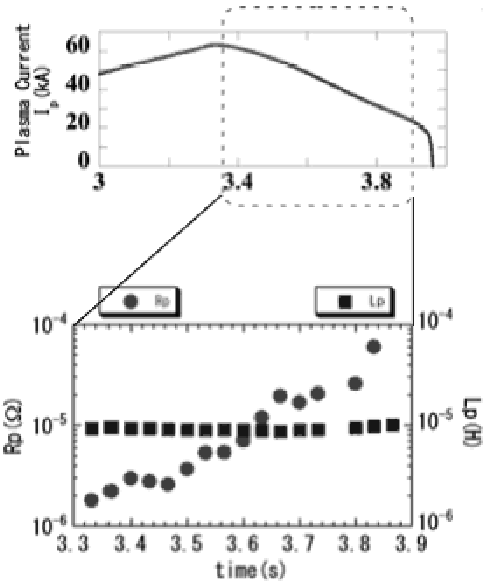

Fig. 1. Waveform of plasma current and temporal evolution of plasma resistance and inductance estimated by the experimental data of Thomson scattering system.

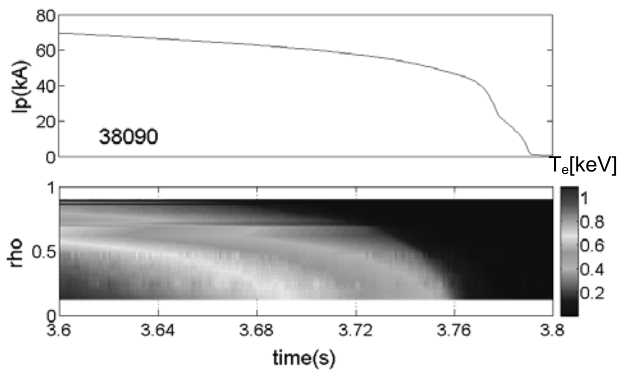

Fig. 2. Waveform of plasma current and temporal evolution of electron temperature profile measured by electron cyclotron emission diagnostic system.

1) D.V. Bartlett, et al., Nucl. Fusion **20** (1980) 1093.
2) K.Y. Watanabe, et al., Controlled Fusion and Plasma Physics **24B** (2000) 1316.