§40. Evaluation of Mercier Parameter Just before Beta Collapse by MHD Instability in LHD Plasma

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In toroidal magnetic confinement devices, the increase of the plasma beta value is one of the important issues for the achievement of the nuclear fusion plant. The plasma beta is limited by the plasma current and/or pressure driven MHD instabilities. The minor collapse and disruption are occurred by MHD instabilities in tokamak plasmas. In the LHD experiments, the beta collapse phenomenon has been observed by MHD instability in the week shear configuration. This study's purpose is to clarify the threshold of the beta limit by the evaluation of the Mercier parameter D_I.

In this paper, we have calculated the equilibrium of LHD plasma just before the beta collapse by using VMEC code[1)]. In a past evaluation, we had calculated the equilibrium by using the plasma pressure, which is measured by Thomson scattering system, and the rotational transform ι profile assumed as uniform, parabolic and hollow current density profile. Because the estimated D_I had large scatter, it was found that the current density profile is important in order to precisely estimate D_I. Therefore, it is used for the calculation of the equilibrium that ι profile was measured by motional Stark effect (MSE) diagnostic.

Because the plasma current is necessary to form the week shear configuration, the plasma current was generated by unbalanced Neutral Beam (NB) injection. For example, over 100 kA of plasma current was observed by unbalanced NB injection in LHD device[2)]. Figure 1 shows the temporal evolution of the plasma current, line averaged electron density and plasma beta with the beta collapse. The plasma current monotonically increases and the beta collapse is occurred at about t = 3.85 sec, I_p = -8.7 kA, n_e = 1.2 x 10^{19} m^{-3} and $\langle\beta_{dia}\rangle$ = 1.3 %.

The electron temperature profiles at around t = 3.7 ~ 3.87 sec are shown in Fig. 2. It is found that the electron temperature profile becomes flat at around ρ = 0.6 ~ 0.8 just after the beta collapse. Figure 3 shows profiles of ι and D_I. In Fig.3, opened circles indicate ι profile measured by MSE diagnostic at t = 3.7 sec. The fitting curve is ι profile calculated by the polynomial fitting of plasma current profile. The curve of D_I is evaluated by the measured pressure profile and fitting curve of ι. From the measurement of ι profile, it is found that resonant surface of m,n = 1/1 is located at about ρ = 0.6. This result is not corresponding to the flattening of electron temperature profile of Fig. 2. It is considered that the measurement time of MSE diagnostic is earlier than the time of electron temperature profile flattening. In this paper, we indicate that D_I could be evaluated by using MSE diagnostic before the beta collapse. In addition, it is necessary that ι profile is measured just before the beta collapse to precisely estimate D_I.

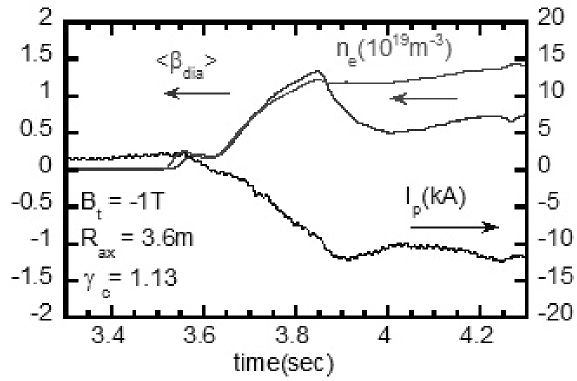

Fig. 1. Typical waveform of the plasma beta $\langle\beta_{dia}\rangle$, current I_p and line averaged electron density n_e with beta collapse. Shot number is 104131.

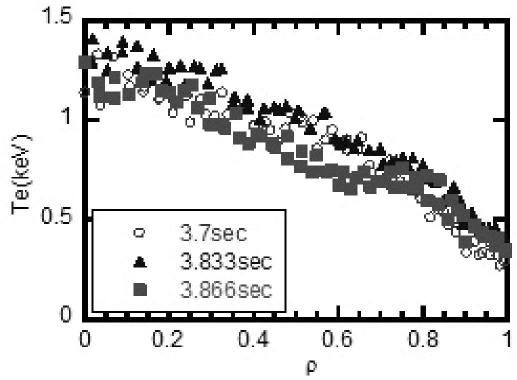

Fig. 2. Electron temperature profile measured by Thomson scattering system.

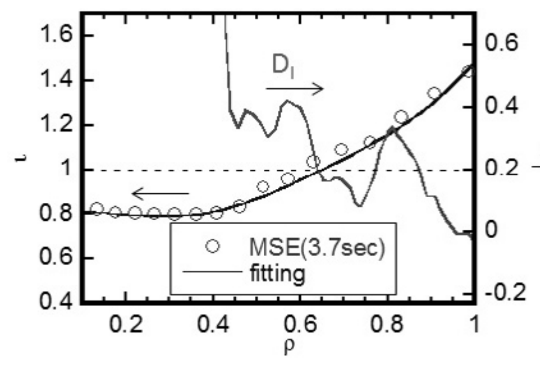

Fig. 3. Profiles of rotational transform ι and Mercier parameter D_I. Rotational transform profile is measured by MSE diagnostic and calculated by the polynomial fitting of plasma current profile.

1) S.P. Hirshman, W.I. Van Rije and P. Merkel, Comput. Phys. Commun. **43** (1986) 143.
2) K.Y. Watanabe, et al., Controlled Fusion and Plasma Physics **24B** (2000) 1316.