§27. On the Reconstruction in LHD High Beta Plasmas

Watanabe, K.Y., Yamaguchi, T. (Grad Univ.),
Narihara, K., Tanaka, K., Suzuki, Y.

The establishment of the identification of MHD equilibrium is one of the very important subjects in the torus plasma study. in helical systems, strictly speaking, the nested magnetic surfaces do not exist, the practical magnetic surfaces exist, which is calculated by the numerical calculation. The above practical magnetic surfaces are predicted to be stochastic as the beta and PS currents increase by a theoretical calculation. In the above situation, we meet some difficulties when we identify the MHD equilibrium configuration in high beta and in peripheral region. Here we consider the more consistent method of the identification of the MHD equilibrium configuration.

Figure 1 shows a reconstructed MHD equilibrium for a LHD high beta operation with $<\beta_{dia}>\sim 2.9\%$ by HINT code. The observed pressure profile at the equatorial plane of the horizontally elongated cross section is shown in Fig.1 (circles). The solid line corresponds to the input data of pressure profile of HINT code. Here the applied boundary condition in HINT calculation is that the pressure set to zero where the field line connects to a wall before 1 toroidal turn and the pressure should be same with the field line averaged value over the 2 toroidal turns as a default so that the observed peripheral pressure profile is reproduced well. The center of the peripheral flux surface estimated by the constant pressure surface is predicted to be shifted torus outwardly by ~5cm, which corresponds to ~9% of the averaged plasma minor radius. The torus outboard location of the OMFS in the high beta value of $<\beta_{dia}>\sim 2.9\%$ is predicted to be almost same with that of the OMFS of vacuum, the inboard location is shifted to torus-outwardly, and the volume of the OMFS is reduced by ~8% comparing with that of vacuum.

Next we study the relationship between the connection length to a wall and the electron mean free path to consider the force balance of the MHD equilibrium in a open field line region. Figure 2 shows the observed electron temperature and density profiles, electron mean free (λ_e) in a high beta LHD discharge with $<\beta_{dia}>\sim 2.9\%$, which is for the same discharge and time slice with Fig.4. In a high beta operation with $<\beta_{dia}>\sim 2.9\%$, the central electron temperature and the density are ~0.5KeV and $\sim 2.7\times 10^{19}\mathrm{m}^{-3}$, respectively. They are fairly low temperature and density because of the low operational magnetic field strength (B_0=0.5T). The connection length of the magnetic field line to a wall and the connection length between the torus-top and the bottom ($L_{C\text{-}TB}$) predicted by HINT are shown by solid lines in Fig.2. It should be noted that when $L_C< L_{C\text{-}TB}$, an MHD equilibrium current cannot flow for the equilibrium force balance. In the LHD high beta operation with $<\beta_{dia}>\sim 2.9\%$, $L_C > L_{C\text{-}TB}$ is always satisfied in the region with a finite electron pressure. And the region with the short electron mean free path, λ_e<10m, is widely spread in the peripheral region. Especially in an open magnetic field region shown by shadow in Fig.2, where the maximum of the field lines corresponds to less than 40 toroidal turns, $\lambda_e/ L_{C\text{-}TB}$ is less than 0.2, which is too small. In the above region, there is a possibility that a finite pressure gradient along the magnetic field line exists. The above fact suggests that in order to reproduce a more consistent MHD equilibrium with the experimental condition, we might take the inertial term ($\mathbf{v}\cdot\nabla\mathbf{v}$) the viscosity and/or the anisotropic pressure, in the force balance equation into account. How large these effects influence the magnetic surfaces and the magnetic field line structure in the peripheral region is one of the big open issues.

[1] Harafuji K. et al ., *J. Comput. Phys.* **81** 169 (1989).

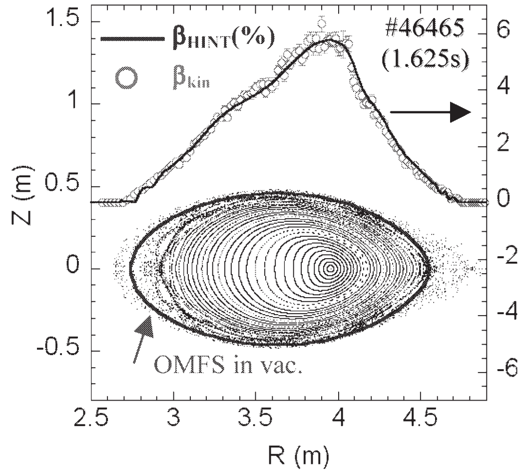

Fig.1 Predicted magnetic field structure by HINT and observed pressure profile in a high beta LHD discharge with R_{ax}^{V}=3.6m, B_0=0.5T and $<\beta_{dia}>\sim 2.9\%$.

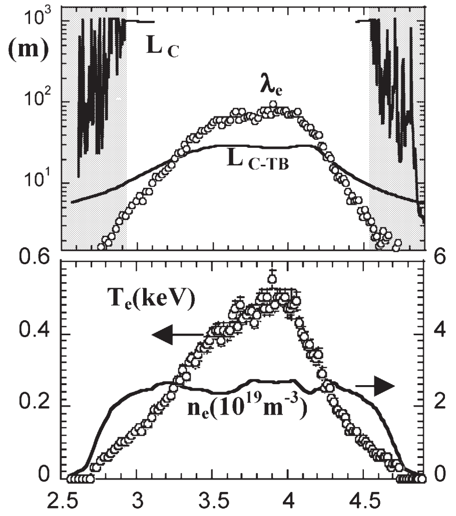

Fig.2 Observed electron temperature and density profiles, electron mean free in a high beta with $<\beta_{dia}>\sim 2.9\%$. Predicted L_C and $L_{C\text{-}TB}$ by HINT are shown. Shadow region denotes an open magnetic field region, where the min. of L_C is less than 40 toroidal turns.