§5. Diverter Field Lines in High Beta LHD Plasma

Watanabe, T., Hojo, H. (Univ. Tsukuba)

MHD equations $\boldsymbol{\nabla} P = \boldsymbol{J} \times \boldsymbol{B}$ are possible to be solved without approximations, under the rotating helical coordinate system (X, Y, ζ), which rotates in synchronization with helical coils. ζ is the axial coordinate. Arbitrary functions $P(\Psi)$ and $I(\Psi)$ are introduced and plasma current is expressed as follows,

$$\boldsymbol{J} = \frac{1}{\mu_0} I'(\Psi) \boldsymbol{B} + P'(\Psi) \begin{pmatrix} -kY \\ kX \\ 1 \end{pmatrix}, \quad \gamma \equiv k \cdot a_c, \quad (1)$$

where γ is the helical pitch parameter, k and a_c are the axial wavenumber and radius of current distribution center of the helical coils, respectively. Ψ is the flux function and $P(\Psi)$ is the plasma pressure distribution. Magnetic field $\boldsymbol{B}$, vector potential $\boldsymbol{A}$ and the magnetic flux function Ψ can be calculated by Biot-Savart law. The relaxation scheme is possible to solve the self-consistent equilibrium flux function Ψ.

Plasma stability is determined by the MHD potential energy,

$$W = \int \mathrm{d}V \left(\frac{3}{2} P + \frac{1}{2\mu_0} \boldsymbol{B}^2 \right) \equiv W_T + W_B \,. \quad (2)$$

W minimum configuration is an MHD stable equilibrium. Equilibriums with $\delta W < 0$ configuration have no beta collapse because transition to vacuum state is energetically prohibited.

We have assumed that the driven current is not present ($I'(\Psi) = 0$). The pressure profile $P(\Psi)$ is assumed to be

$$P(\Psi) = \beta_{\mathrm{ax}} \frac{\boldsymbol{B}_{\mathrm{ax}}^2}{2\mu_0} \frac{\sum_{i=1}^{3} P_i \exp\left\{ -D \left(\frac{\Psi}{\Psi_{\mathrm{s}}} \right)^i \right\}}{P_1 + P_2 + P_3}, \quad (3)$$

where β_{ax}, P_1, P_2, P_3 and D are some constants. $\boldsymbol{B}_{\mathrm{ax}}$ and Ψ_{s} are the magnetic field on the magnetic axis and the value of Ψ at the separatrix, respectively. The functional form (3) can express from peaked type to flat flat-top type pressure profiles.

It has been confirmed that small γ configurations are strongly MHD stable. We have also found a possibility that high power heating causes a bootstrap transition from the peaked pressure distribution to the flat type pressure distribution(Fig.1). There is no significant topological deformation in the shape of the diverter leg of LHD configurations(Fig.2)

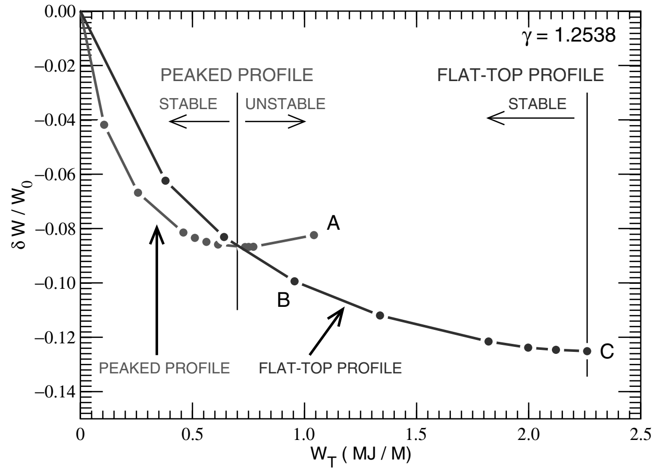

Fig. 1: abscissa: Plasma stored thermal energy W_T. ordinate: Variation of MHD potential energy δW. $\gamma = 1.2538$ is one of a standard helical pitch parameter of the LHD.

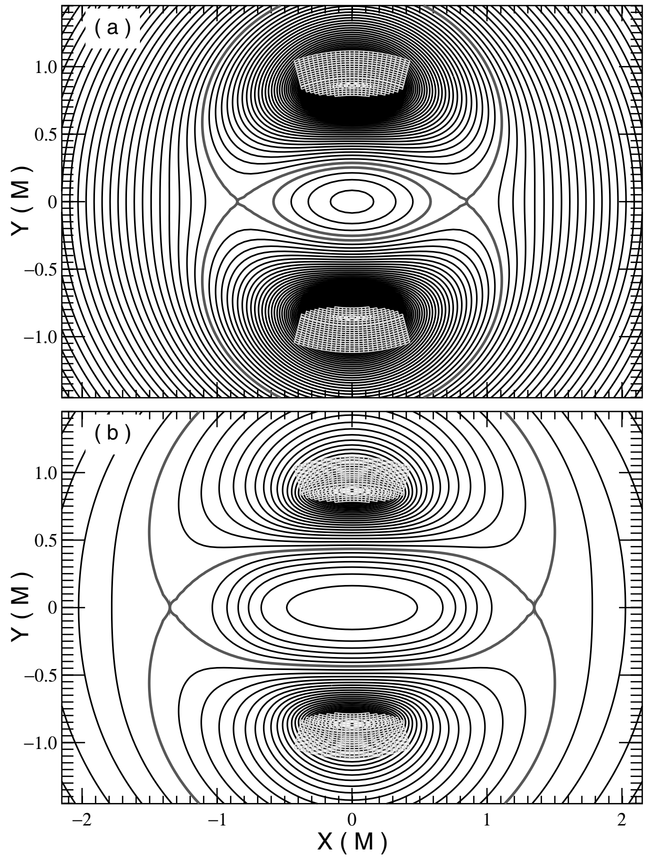

Fig. 2: Comparison of the magnetic surface and diverter leg configurations ($\gamma = 1.1221$). Vacuum(a) and Ultra-high beta equilibrium ($\beta_{\mathrm{ax}} = 176\%$) (b) magnetic field configurations. Cross-section of helical coils are also shown.

1) T. Watanabe and H. Hojo, "Helical pitch parameter dependency of high beta equilibrium of helical plasmas", Plasma Fusion Res. (submitted, 2010).

2) T. Watanabe and A. Sagara, "Bootstrap transition to high beta equilibrium in helical system", Plasma Fusion Res. (submitted, 2010).