§33. The Marginally Stable Pressure Profile and a Possibility of High Beta Plasma Confinement in LHD

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It is shown theoretically that LHD has potentiality of the high beta plasma confinement. The chaotic field line-layer, which surrounds the outside of the outermost magnetic surface, plays a key role for an efficient plasma confinement in LHD.

High shear LHD magnetic field configuration has following merit for plasma confinement: (1) Unstable resonant modes are localized on the rational surface so that these instabilities do not relate directly to the decay of the entire plasma column. (2) The magnetic shear has a strong stabilizing effect for the convective instability of entire plasma column. (3) The magnetic field line in the chaotic region has extremely long connection length. Characteristic of chaotic field line region and its role for the plasma confinement in LHD can be summarized as follows: (1) The connection length of the diverter field line which approaches close to the outermost magnetic surface exceeds 10 km. The cold diverter plasma does not cool down the core plasma directly therefore. (2) The lines of force that are disengaged from the chaotic field line region reach the vacuum vessel wall soon. Then, it is expected in chaotic field line region that the plasma pressure can be sustained stably by the line-tying effect of the field lines, which are disengaged from the chaotic field region. (3) The chaotic field line region can confine the reflecting particles (particles whose velocity is almost perpendicular to the magnetic field). (4) The plasma pressure of the chaotic field line region can increase the core plasma pressure, even in the case of the magnetic hill configuration. (5) The plasma contained in the chaotic field line region prevents an immediate core plasma cooling down caused by the neutral atom flitting in the vacuum vessel (role of the plasma blanket).

The Grad-Shafranov equation is extended to 3D configuration in order to solve the high beta equilibrium of a helical plasma. It is assumed that nested magnetic flux function can exist and that the plasma pressure is a function of the flux function.

MHD stability analysis is carried out for the LHD plasma surrounded by the chaotic field line region, which can sustain stably the steep pressure gradient at the peripheral region of LHD plasma. The stability condition is summarized in simple and compact formulae for the resonant helical mode and for the convective mode.

The marginally stable pressure profile are derived by these formulae and numerical solved as shown in Fig.1 For simplicity, we have assumed LHD vacuum magnetic field with $R_{ax} = 3.6$m and $B_{ax} = 2.75$T. and toroidal plasma current is assumed to be $I_t = 0$.

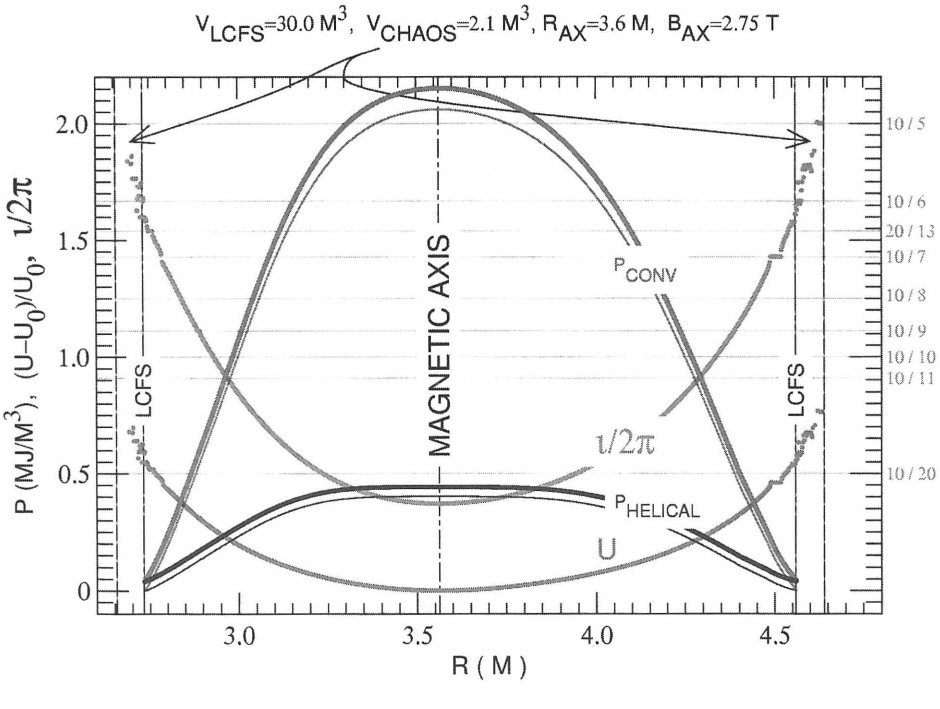

Figure 1: Numerical examples of marginally stable pressure profile of LHD in the oblong cross section.

Axis of abscissas is the major radius R. Marginal pressure profile for the helical (convective) mode is shown by $P_{HELICLA}$ (P_{CONV}). The plasma pressure of the chaotic field line region ($n_{LCFS}T_{LCFS}$) is assumed to be 0 or to be $5 \times 10^{19} \times 5$ ($\mathrm{m}^{-3} \cdot \mathrm{keV}$). LCFS specifies the positions of the last closed flux surface. The distribution of the rotational transform $\iota/2\pi$ and the profile of magnetic hill U are also plotted. The chaotic field line region is also shown in the figure.