§3. Suppression of Core Density Collapse by Plasma Elongation Control

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Core density collapse (CDC) is observed in internal diffusion barrier (IDB) plasmas [1]. CDC inhibits further increase of the central pressure and the fusion triple product. Therefore, it is fairly important to suppress CDC. Necessary conditions for CDC has been investigated in [1], *i.e.* $\beta_0^* \geq 3.5$ %, $R_0^{\mathrm{h}} \geq 4.1$ m, and $R_{90}^{\mathrm{h\_in}} > R_1^{\mathrm{v\_in}}$, where R_0^{h}, $R_{90}^{\mathrm{h\_in}}$, and $R_1^{\mathrm{v\_in}}$ denote the radial positions of the plasma center, $\beta^* = 0.1 \times \beta_0^*$ at a horizontally elongated slice (inboard side) and the last-closed-flux-surface (LCFS) at a vertically elongated slice in the vacuum configuration (inboard side), respectively. The third threshold means that the CDC takes place when the inboard side plasma edge on the equatorial plane becomes circular in the toroidal direction. This deformation of the plasma shape is due to the large Shafranov shift.

In LHD, a set of magnetic field coils is equipped to control the quadrapole field. The magnetic field induced by this coil is called as "B_{Q}" and B_{Q} is defined as 100 % when it completely cancels the quadrapole magnetic field in the vacuum configuration. The plasma elongation is controllable with this B_{Q}. Here, we introduce an effective elongation parameter, κ_{eff}, which is defined by the ratio of the central line-density measured on a vertically elongated slice to that measured on a horizontally elongated slice. The κ_{eff} increases with decreasing B_{Q}, for example. In the case of $B_{\mathrm{Q}} < 100$ % ($B_{\mathrm{Q}} > 100$ %), the plasma shape is compressed horizontally (vertically) at any toroidal angle, and we call this vertical (horizontal) elongation. The maximum plasma volume is obtained at $B_{\mathrm{Q}} = 100$ %. Vertical elongation is effective to suppress the Shafranov shift and therefore the deformation of the plasma shape as is shown in Fig. 1, where $R_{90}^{\mathrm{h\_in}}$ is plotted against β_0^* for $B_{\mathrm{Q}} = 25$ % and 100 %. In the case of $B_{\mathrm{Q}} = 100$ %, $R_{90}^{\mathrm{h\_in}}$ increases with β_0^* and CDC takes place when β_0^* reaches ~ 5.5 % and $R_{90}^{\mathrm{h\_in}}$ becomes $> R_1^{\mathrm{v\_in}}$. In the case of $B_{\mathrm{Q}} = 25$ %, on the other hand, $R_{90}^{\mathrm{h\_in}}$ is kept well below $R_1^{\mathrm{v\_in}}$, even though β_0^* exceeds 5.5 %. As a result, no CDC is observed in the case of $B_{\mathrm{Q}} = 25$ %.

Results of the B_{Q} scan experiments performed in outward shifted configurations of $R_{\mathrm{ax}} = 3.75$ and 3.85 m are summarized in Figs. 2 and 3, where $R_{90}^{\mathrm{h\_in}}$ is plotted against κ_{eff} for fixed ranges of β_0^*. In low β_0^* datasets, $R_{90}^{\mathrm{h\_in}}$ monotonically increases with κ_{eff} as is expected for vertical elongation. A nonlinear response of $R_{90}^{\mathrm{h\_in}}$ is recognized in the high β_0^* datasets of $\beta_0^* > 2$ % in $R_{\mathrm{ax}} = 3.75$ m (Fig. 2) and $\beta_0^* > 3$ % in $R_{\mathrm{ax}} = 3.85$ m (Fig. 3). Because of this nonlinear response, there is an optimum κ_{eff} to keep $R_{90}^{\mathrm{h\_in}}$ apart from the CDC threshold of $R_{90}^{\mathrm{h\_in}} > R_1^{\mathrm{v\_in}}$. The optimum κ_{eff} for $R_{\mathrm{ax}} = 3.75$ and 3.85 m are ~ 1.2 and ~ 1.3, respectively. It should be also noted that the margin to the CDC threshold is larger in $R_{\mathrm{ax}} = 3.75$ m than in $R_{\mathrm{ax}} = 3.85$ m.

Reference

[1] J. Miyazawa *et al*., Ann.Rep.Apr.2006-Mar.2007, 7p.

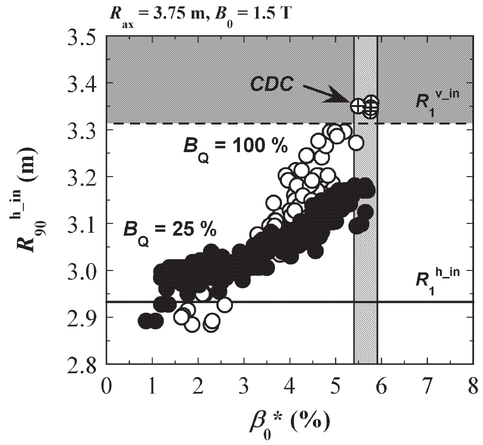

Fig. 1. β_0^* dependence of $R_{90}^{\mathrm{h\_in}}$ in a vertically elongated configuration of $B_{\mathrm{Q}} = 25$ % (closed circles) compared with that in the normal configuration of $B_{\mathrm{Q}} = 100$ % (open circles). CDC takes place in the case of $B_{\mathrm{Q}} = 100$ % (marked by crosses).

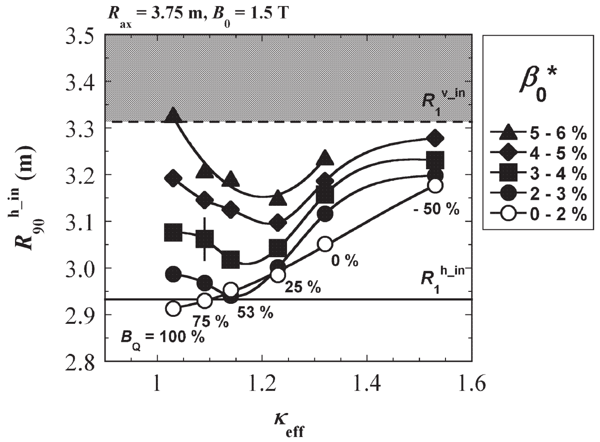

Fig. 2. Summary of κ_{eff} (B_{Q}) dependence in an outward shifted configuration of $R_{\mathrm{ax}} = 3.75$ m and $B_0 = 1.5$ T. Different symbols denote the range of β_0^*.

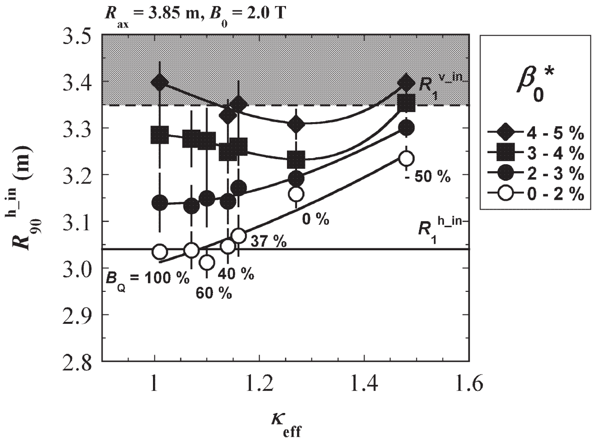

Fig. 3. Summary of κ_{eff} (B_{Q}) dependence in an outward shifted configuration of $R_{\mathrm{ax}} = 3.85$ m and $B_0 = 2.0$ T. Different symbols denote the range of β_0^*.