§6. Formularization of the Confinement Enhancement Factor as a Function of the Heating Profile

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The confinement enhancement factor, $\gamma_{DPE}$, used in the Direct Profile Extrapolation (DPE) method [1] has been formularized using the peaking factor of the neutral beam (NB) heat deposition profile, $(P_{dep}/P_{dep})_{avg}$, which is the line-average of $(P_{dep}/P_{dep})$ inside $\rho \leq 1$, and

$$P_{dep}(\rho) = \int_0^\rho P_{dep}(dV/d\rho)_{exp} \, d\rho.$$  (1)

$P_{dep}$ is the total NB heating power.

In the DPE method, the gyro-Bohm normalized electron pressure profile is defined by $P_{exp} = (P_{dep}/P_{dep})_{avg}$, which is the line-average of $(P_{dep}/P_{dep})$ inside $\rho \leq 1$, and

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In the DPE method, the gyro-Bohm normalized electron pressure profile is defined by $P_{exp} = (\rho_{exp}/\rho)^{2/3}$. This can be fitted by the zero-order Bessel function of $\alpha_0 J_0(2.4 \rho/\rho_0)$, $\alpha_0 J_0(2.4 \rho/\rho_0^{*})$, as shown in Fig. 1, where all profile data are used to obtain $\alpha_0$ and $\alpha_0^{*}$ (thin solid lines in Fig. 1), while the profile data in the outer region of $0.5 < \rho \leq 1$ are used to obtain $\alpha_{0*}$ and $\alpha_{0*}^{*}$ (bold broken lines in Fig. 1). In LHD, the pressure profile occasionally shows flattening in the core region as shown in Fig. 1(a). This is what we call the core confinement degradation. The physics mechanism of this is not understood yet. The latter model with $\alpha_0$ and $\rho_{exp}$ has been introduced to estimate the core pressure profile from the data in the outer region of $0.5 < \rho \leq 1$ in the case with the core confinement degradation.

In Fig. 2, shown are the dependences of the plasma parameters on the line-averaged electron density, $n_{e,exp}$. The magnetic stored energy, $W_{m}$, shows the gyro-Bohm type density dependence ($W_{m} \propto n_{e,exp}^{0.6}$) often degrades at high-density. This is called the global confinement degradation, and is clearly observed in the plasmas fuelled by gas puffing (GP). In the plasmas fuelled by hydrogen ice-pellet injection (PI), the gyro-Bohm type density dependence is kept even in the high-density regime reaching $10^{20}$ m$^{-3}$. However, the value is slightly smaller than that expected from low-density GP data (Fig. 2(a)). This global degradation is related to the heating profile that changes from centrally peaked to flat to hollow as the density increases (Fig. 2(d)) and the NB penetration length becomes shallow.

Regression analysis using over 800 profile data gives a relation of $\alpha_{0*} \propto (P_{dep}/P_{dep})_{avg}^{0.6}$. If we assume for FFHR-d1 that 1) the core confinement degradation can be avoided, 2) the global confinement is proportional to $\alpha_{0*}$, and 3) the peaking factor of the alpha heat deposition profile is 0.65, then $\gamma_{DPE}$ is given by

$$\gamma_{DPE} = (0.65 / (P_{dep}/P_{dep})_{avg})^{0.6}.$$  (2)

References: