§3. Confinement Property of Gas-Fuelled High-Density LHD Plasmas

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It has been observed that a favorable positive density dependence of the energy confinement time as predicted by the ISS95 scaling is lost in gas-fuelled high-density LHD plasmas. In such a high-density region, electron pressure profiles exhibit "stiffness", where the characteristic length of the electron pressure gradient, L_p ($\equiv$ $(-\mathrm{d}(\ln p_e)/\mathrm{d}\rho)^{-1}$) is robust to the NB power deposition profiles. This can be recognized in the hatched density region in Fig. 1. Such a stiff profile is reproduced by a model equation of

$$p_e^{\mathrm{model}} = p_{e0} \exp(-(1.5\rho^2 + 1.5\rho^{10})). \qquad (1)$$

In the same density region, p_e itself increases according to the NB heating power, as shown in Fig. 2. From this observation, we obtain

$$p_{e0} = 3.4\ P_{\mathrm{abs}}^{0.51}, \qquad (2)$$

as the factor in Eq. (1), where $P_{\mathrm{abs}} = P_{\mathrm{NB}}^{\mathrm{MES}} - \mathrm{d}W_p^{\mathrm{dia}}/\mathrm{d}t$. Volume integration of p_e^{model} gives the model electron stored energy, W_e^{model}. It is possible to determine an operational region where the stiffness appears by comparing the p_e profile with the p_e^{model}.

We have compared the electron-stored energy, W_e^{exp}, at various experimental conditions, with the W_e^{model}. Examples of comparison are shown in Fig. 3, where three kinds of dataset are used. In the dataset of $R_{\mathrm{ax}} / B_0 = 3.6$ m / 1.5 T, W_e^{exp} is well reproduced by W_e^{model} in the plateau regime. In the outward-shifted configuration of $R_{\mathrm{ax}} / B_0 =$ 3.75 m / 1.5 T, W_e^{model} also matches with W_e^{exp}, but at higher collisionality near the Pfirsh-Schlüter (P-S) regime. As for the high magnetic field case of $R_{\mathrm{ax}} / B_0 = 3.6$ m / 2.75 T, the ratio of $W_e^{\mathrm{exp}} / W_e^{\mathrm{model}}$ is systematically higher than 1. The maximum of this ratio suggests a hidden parameter dependence of the model, which is proportional to B_0. This can be incorporated to our model and then Eq. (2) becomes,

$$p_{e0} = 2.3\ B_0\ P_{\mathrm{abs}}^{0.51}. \qquad (3)$$

In the high B_0 dataset, however, $W_e^{\mathrm{exp}} / W_e^{\mathrm{model}}$ begins to decrease as the collisionality increases. This can be attributed to the NB power deposition profile effect, *i.e.* the penetration depth of the NB decreases at such a high collisionality region. Indeed, a similar kind of deterioration can be recognized in the dataset of $R_{\mathrm{ax}} / B_0 = 3.6$ m / 1.5 T, where $W_e^{\mathrm{exp}} / W_e^{\mathrm{model}}$ decreases as the collisionality increases in the P-S regime. In these cases, the NB power deposition profiles are flat and much different from the peaked profile in the lower collisionality plasmas. Even though the power deposition profile changes, the profile shape of $p_e(\rho) \sim \exp(-(1.5\rho^2 + 1.5\rho^{10}))$ scarcely changes. This is what is called "stiffness".

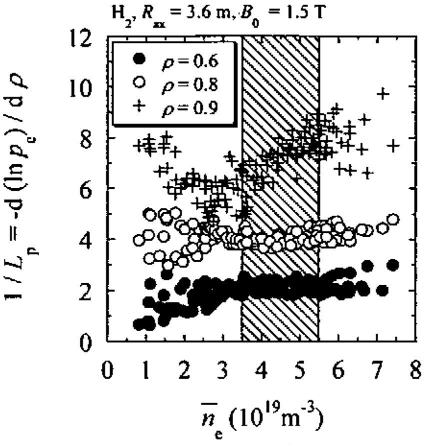

Fig. 1. Density dependence of L_p^{-1} at different positions. Although the NB heating power varies from 2.5 to 10 MW, L_p^{-1} scarcely changes at the hatched density region, except the plasma edge ($\rho = 0.9$) and the plasma core ($\rho < 0.3$, not shown).

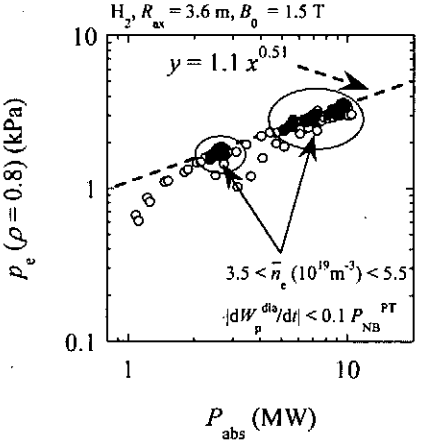

Fig. 2. NB input power dependence of a local electron pressure at $\rho = 0.8$. Closed circles denote the data in the hatched density region in Fig. 1.

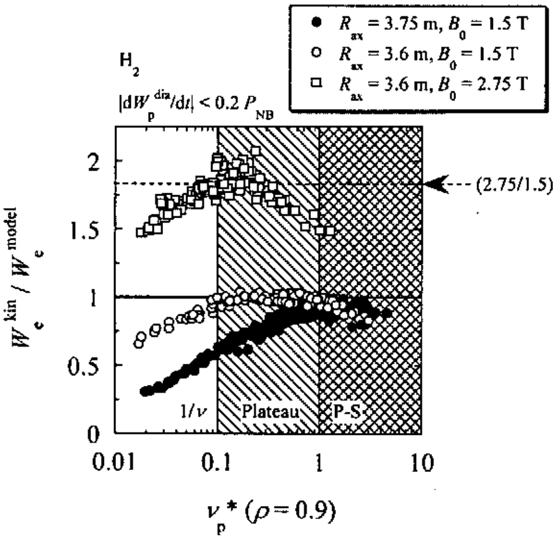

Fig. 3. Comparison between the electron stored energy and the model. Abscissa is the collisionality, $\nu_p^* = \nu_{ei} R / (v_T^e(\iota/2\pi))$, at $\rho = 0.9$.