§14. Global Electron Energy Confinement of Neon Plasmas in LHD

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Neon gas puff experiment has been performed to investigate the response of the energy confinement property to the electric charge and the mass of the plasma ions. In this study, we focus on the global energy confinement of electrons in the plasmas heated by the neutral beam (NB) injection [1]. Only the hydrogen (or the neon) gas is puffed into plasmas denoted as 'hydrogen' (or, 'neon') plasmas. The plasma major radius, R, and the plasma minor radius, a, are fixed to 3.6 m and 0.62 m, respectively. Meanwhile, the magnetic field strength at the plasma center, B_0, is changed from 1.5 T to 2.893 T. The relation between T_{e0} and the electron heating power per an electron, P_{NB_e} / $\langle n_e \rangle$, is plotted in Fig. 1. In the range of $P_{NB\_e} / \langle n_e \rangle < 5$ MW / 10^{19} m^{-3}, T_{e0} monotonically increases with $P_{NB\_e} / \langle n_e \rangle$, and any particular differences between the hydrogen and the neon plasmas can be recognized in this region. The maximum T_{e0} obtained in the neon plasmas can be attributed to the increased heating power due to the small fraction of the NB shine-through power at the low-density region. Above $P_{NB\_e} / \langle n_e \rangle > 5$ MW / 10^{19} m^{-3}, however, T_{e0} gradually decreases. The reason why this kind of deterioration occurs is not solved to date.

Next, we compare the global energy confinement of the electrons in the hydrogen and the neon plasmas. Data points are selected according to three criteria; (a) $\langle n_e \rangle < 2 \times 10^{19}$ m^{-3} (to eliminate the data that are in the saturated regime of the positive density dependence of W_{e_kin}), (b) $P_{ei} / P_{NB} < 0.1$ (to reduce the influence of P_{ei}), and (c) $P_{NB\_e} / \langle n_e \rangle < 5$ MW / 10^{19} m^{-3} (to eliminate the data that indicate the deterioration of the positive dependence of T_{e0} to $P_{NB\_e} / \langle n_e \rangle$). The non-dimensional regression analysis of the experimental electron energy confinement time, $\tau_{E\_e}^{exp}$ ($\equiv W_{e\_kin} / P_{NB\_e}$) is examined. In the non-dimensional form, $\tau_{E\_e}^{exp}$ can be expressed as [1]

$$\tau_{E\_e}^{exp}\,\Omega \propto B_0\, \tau_{E\_e}^{exp} \propto (\rho_e^*)^{\phi} (\nu^*)^{\gamma} (\beta_e)^{\eta}. \quad (1)$$

However, the linear correlation coefficients for ν^* and β_e are small (less than 0.55) compared with that of ρ_e^* (more than 0.88), for both of the hydrogen and the neon datasets. Therefore, we neglect the dependence on ν^* and β_e. Regression analysis with ρ_e^* alone gives;

$$B_0\, \tau_{E\_e}^{exp}\,(\mathrm{H}) = 3.57 \times 10^{-13}\, (\rho_e^*)^{-2.74\pm0.07}, \quad (2)$$

for hydrogen dataset, and

$$B_0\, \tau_{E\_e}^{exp}\,(\mathrm{Ne}) = 1.15 \times 10^{-12}\, (\rho_e^*)^{-2.61\pm0.09}, \quad (3)$$

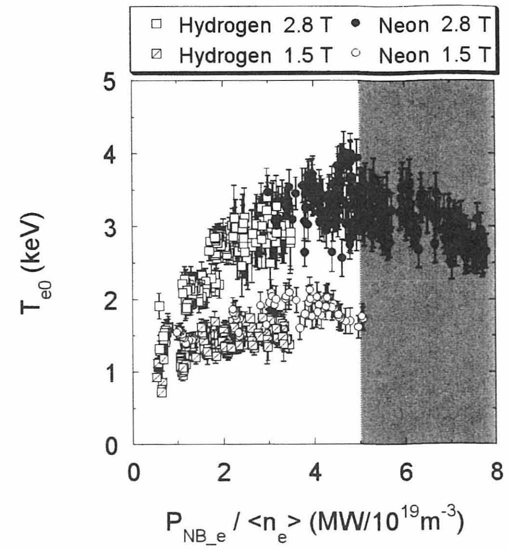

Fig. 1. Dependence of T_{e0} on $P_{NB\_e} / \langle n_e \rangle$. Plotted are the data that satisfy the two criteria; (a) $\langle n_e \rangle < 2 \times 10^{19}$ m^{-3}, and (b) $P_{ei} / P_{NB} < 0.1$.

for the neon dataset. This suggests that both plasmas have similar parameter dependence of the global electron energy confinement. The difference in the coefficients between Eqs. (2) and (3) is possibly due to the small ρ_e^* of ~ 10^{-4} (note that even the small difference of 0.1 in the exponents causes an error of factor 2.5 in the coefficients). To compare the coefficients more accurately, we assume a model equation with the exponent of – 2.7;

$$\tau_{E\_e}^{fit}\,\Omega \propto B_0\, \tau_{E\_e}^{fit} \propto (\rho_e^*)^{-2.7}$$
$$= C_0\, a^{2.30}\, R^{0.574}\, B_0^{0.723}\, P_{NB\_e}^{-0.574} \langle n_e \rangle^{0.574}, \quad (4)$$

where C_0 is the fitting parameter, and the units of each terms are; m, m, T, MW, and 10^{19} m^{-3}, for a, R, B_0, P_{NB_e}, and $\langle n_e \rangle$, respectively. Using hydrogen dataset, $C_0 = 0.059\pm0.007$ is obtained, while $C_0 = 0.055\pm0.004$ is obtained with the neon dataset. In both cases, C_0 is identical within the standard deviations.

These results are contrastive to the Z-mode and the RI-mode in tokamaks, where a reduction of the electron thermal diffusivity induced by the impurity (including the neon) gas puff has been observed. In this study, however, parameter region is limited. Especially, the confinement deterioration at $P_{NB\_e} / \langle n_e \rangle > 5$ MW / 10^{19} m^{-3} is observed only in the neon plasmas. Whether this deterioration will also occur in the hydrogen plasmas, or not, should be examined in the future experiment.

Reference

1) Miyazawa, J. et al., paper presented at 29th EPS, P-1.073, 2002, Montreux, Switzerland.
2) Goldston, R. J. et al., Bull. Am. Phys. Soc. **34**, 1964 (1989).
3) Murakami, M. et al., Phys. Fluids B **3**, 2261 (1991).