§19. Evaluation of Heating Efficiency Property of Perpendicularly Injected NB in LHD High Beta Plasma

Seki, R., Funaba, H., Watanabe, K.Y., Ohdachi, S., Suzuki, Y.

In the Large Helical Device (LHD), the reactor-relevant high-beta plasmas with the volume averaged beta value, <β>~5%, are achieved in low field strength [1]. In the reactor, the high beta plasma is maintained in the high-field strength. To closer reactor parameters, the high-beta discharge with higher field strength is attempted. In the higher field strength of LHD, a heating efficiency of a perpendicularly injected neutral beam (perp-NB) becomes higher than that in the low field strength. It is important for optimization of heating power and transport analyses to evaluate the heating power properly. Therefore, to validate the tendency of heating efficiency which predicted by simulation, we roughly evaluate the heating efficiency of perp-NB from the measurements of stored energy in the experiments of the perp-NB modulation.

In this rough evaluation, the stored energy evaluated from diamagnetic current (W_{dia}) consists of stored energies of bulk plasma (W_{th}) and fast ions (W_f) produced by perpendicularly injected NB as follows.

$$\frac{2}{3}\frac{dW_{\rm dia}}{dt} = \frac{2}{3}\frac{dW_{\rm th}}{dt} + \frac{dW_{\rm f\perp}}{dt} \quad (1).$$

From the energy conservation, the time variation of stored energies of bulk plasma is given by

$$\frac{dW_{\rm th}}{dt} = -\frac{W_{\rm th}}{\tau_{\rm E}} + \frac{W_{\rm f}}{\tau_{\rm relax}} \quad (2),$$

where τ_E is energy confinement time of plasma and τ_{relax} energy relaxation time of fast ion. The stored energies of fat ions in each NB are given from

$$\begin{aligned}\frac{dW_{\rm NB\_n}}{dt} &= P_{\rm birth\_n} - \frac{W_{\rm NB\_n}}{\tau_{\rm relax}} - \frac{W_{\rm NB\_n}}{\tau_{\rm loss}} \\ &= P_{\rm abs\_n} - \frac{W_{\rm NB\_n}}{\tau_{\rm relax}} \end{aligned} \quad (3).$$

The heating power of fast ions is rough evaluated by time variance of W_{dia} as follows.

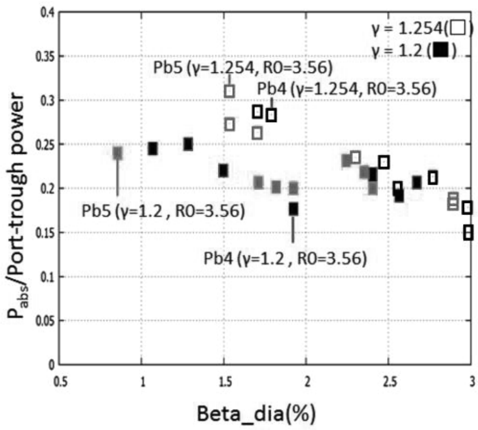
$$\begin{aligned}\frac{dW_{\rm dia}}{dt} &= \pm\sum \alpha_n \frac{3}{2} P_{\rm abs\_n} \\ &\sim \pm\frac{3}{2} P_{\rm abs\_prep-NB}\end{aligned} \quad (4)$$

where

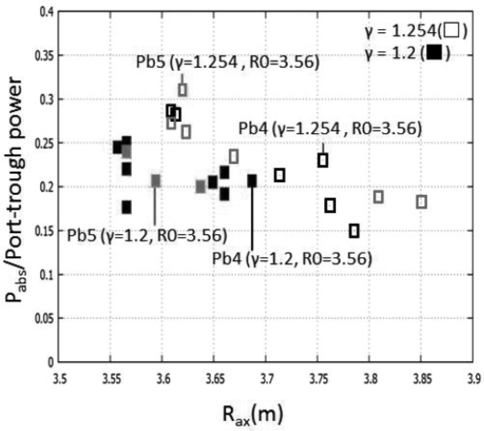
$W_{\rm f} = \sum(1-\alpha_n)W_{\rm NB\_n} + \sum \alpha_n W_{\rm NB\_n}$, and $\alpha_n = \frac{W_{\rm NB\_n\perp}}{W_{\rm NB\_n}}$.

By using the rough evaluation, the ratio of the absorption power of perpendicularly NB to the the port-throguh power is evaluated in the high beta plasma in LHD. In the field strength, Bt = 1 T, the ratio is compared with the different mangnetic field configulations (the magnetic axis of vacumm field, R_0 = 3.56 m, γ = 1.254 and R_0 = 3.56 m, γ = 1.2). In this comparison, a electron temperature Te ~ 1.2 keV and a density ne ~ 3.5 x 10^{19} m^{-3}. Figure 1 shows the heating efficiency with chang in the averged volume beta or magnetic axis of equilibrium field. In these figure, vertical axis is the ratio of the absorption power evaluated by the rough evalutation to port-throgh power. Open square (□) is a case of γ = 1.254, and closed square (■) is γ = 1.2. From figs. 1, the position of magnetci axis shifts torus outside with increase in the averaged volume beta in the case of γ = 1.254. The heating efficinecy in R_{ax} ~ 3.8 decrease from ~0.3 to less than 0.2. On the other hand, the position of magnetci axis in the case of γ = 1.2 changes smaller than that in the case of γ = 1.254 and the heating efficiency rarely changes with change in the averaged volume beta.

In the future, we will improve this rough evaluation for increasing accuracy, and the heating efficinecy evaluated by analyese code will be compared with the heating efficinecy of this rough evaluation.



(a) Averaged volume beta



(b) magnetic axis of equilbrium field

Fig. 1 Comparision of heating efficiency between γ = 1.254 and γ = 1.2.

[1] H. Yamada, et al., Nucl. Fusion **51** (2011) 09421.