# §28. Study of Pellet Injection for Efficient Core Plasma Fuelling in Heliotron J

Motojima, G., Sakamoto, R., Mizuuchi, T., Okada, H., Nakamura, Y. (Kyoto Univ.), Ohyabu, N., Yamada, H., Sano, F. (Kyoto Univ.)

The pellet injection design studies by a pellet ablation code find that the pellet size of 0.8 mm$\phi\times$0.8 mm$\ell$ (cylindrical shape) and the pellet speed of 300 m/s$-$500 m/s are required in Heliotron J.

The major advantage of pellet injection over other fuelling methods is that particles are deposited behind the separatrix in a region where closed magnetic surfaces allow a higher fueling efficiency. Although gas puffing and super molecular beam injection are currently used for the particle refuelling in Heliotron J, the pellet injection is expected to be a higher efficient refuelling system. Moreover, Heliotron J has a robust NBI system compatible with the pellet injection and can elucidate the potential of generation of high performance plasma with high density.

In this study, we have used the ABLATE code[1)] to evaluate the optimized pellet parameters for the device size and plasma parameters of Heliotron J. This code can calculate the ablation rate profile (i.e., the pellet penetration depth) including the effect of non-time or time-dependent profiles of electron temperature and density during pellet ablation. The model is essentially extended from the neutral gas shielding (NGS) model widely accepted as a standard model for explaining the results of tokamak experiments, which estimates heat flux due to thermal electrons and evaluates the shielding effect of ablated neutral gas against it. It should be noted that the effect of fast ion effect is not taken into account in this study. In this model, the recession speed of the pellet surface is given by the form of simple scaling laws[2)]

$$\frac{\mathrm{d}r_p}{\mathrm{d}t} \propto r_p^{-2/3} n_e^{1/3} T_e^{1.64}\ \mathrm{cm/sec} \qquad (1)$$

where $r_p$, $n_e$ and $T_e$ are the equivalent spherical pellet radius, the background electron density, and temperature, respectively.

The pellet size is selected as the increment of plasma density caused by one pellet is $3\times10^{19}$ m$^{-3}$ (This is equivalent to $2.1\times10^{19}$ m$^{-3}$ hydrogen atoms), resulting that the standard pellet size is decided to be 0.8 mm$\phi\times$ 0.8 mm$\ell$. Here, the plasma volume of 0.68 m$^3$ is assumed.

The penetration depth with respect to the pellet speed is analyzed by using ABLATE code. Figure 1 shows the relationship between the pellet speed and the penetration depth. We assumed that the plasma major radius $R$ is 1.07 m, plasma minor radius $a$ is 0.17 m, temperature profile is $T_e = T_i = T_0(1-(r/a)^2)$ eV, density profile is $n_e = 1-((r/a)^8)^2$ [$10^{19}$ m$^{-3}$]. Three cases of the central temperature are assumed: $T_0$ = 500 eV, 700 eV and 1000 eV. At $T_e$ = 1000 eV, the penetration depth to the magnetic axis is attained with the pellet speed of over 800 m/s.

Figure 2 shows the absorption profile at each pellet speed with $T_e$ = 1000 eV. In order to obtain insignificant perturbations from the pellets, the penetration depth over the plasma center may not be unfavorable. Namely, the pellet speed of 300m/s-500m/s may be probably appropriate for the penetration depth between $0.5 < r/a < 0.8$.

Because the required pellet size is relatively small, the establishment of the acceleration techniques different from a general pneumatic system and the production methods of the small pellets are planned for the future.

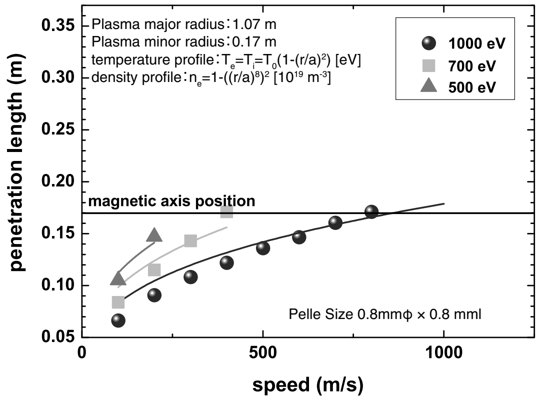


Fig. 1: Penetration depth as a function of pellet speed. Solid line shows the fitting curve of $\propto v^{1/3}$. The penetration depth of a pellet is roughly estimated by using a NGS scaling that is represented by $\lambda/a = 0.079 T_{e0}^{-5/9} n_{e0}^{-1/9} m_{pel}^{5/27} v_{pel}^{1/3}$.

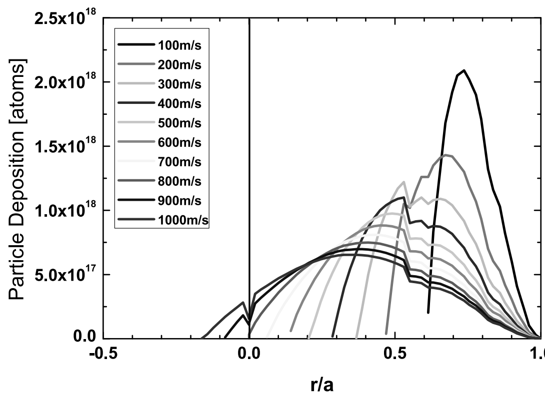


Fig. 2: Absorption profile at each pellet speed with $T_{e0}$= 1000 eV

1) Y. Nakamura *et al.*, Nucl. Fusion **26**, 907 (1986).

2) L.R. Baylor *et al.*, Nuclear Fusion **37**, 445 (1997).