§4. Prospect of Pellet Fueling to High Density Helical Reactor

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A Confinement improvement, which have internal diffusion barrier (IDB) in high density regime, has been found by employing pellet fueling in LHD[1]. This confinement improvement point to alternative scénario for high-density/low-temperature ignition in a helical reactor. Core fueling by pellet injection becomes critical issue in such a reactor scénario, while on the other hand, the deep pellet penetration becomes difficult because of the high temperature and large scale plasma. We have examined the possibility of the core fueling by pellet injection to the FFHR2-series, which are conceptual designs of heliotron type reactor[2].

Under the reactor condition, pellet ablation with 3.5 MeV α particles are concerned in addition to the ablation with thermal plasma. However, it was reported that the ablation rate with α particles are reasonably small compare to that with thermal electrons[3]. Pellet ablation with α particles are, therefore, ignored and a simple neutral gas shielding (NGS) pellet ablation model, which take into account only thermal electron as an energy carrier, is employed. In the NGS model, pellet regression rate is described by the following scaling law[4].

$$\dot{r}_p = 1.72\times10^{-7}\, r_p^{-2/3}\, n_e^{1/3}\, T_e^{1.64} \quad \text{[mm/s]}$$

Pellet size is determined to be the same impact (Δn_e= 6×10^{19} m^{-3}) with LHD experiments, namely the pellet sizes are 8.2 mm for FFHR2 (a= 0.82 m), 11.8 mm for FFHR2m1 (a= 1.19 m) and 16.9 mm for FFHR2m2 (a= 1.92 m). Hydrogen is used for propellant gas to increase pellet velocity and to avoid impurity inflow. Pellet velocity is assumed 1500 m/s from the ideal gun theory with empirical correction.

Figure 1 shows assumed plasma profile, which is based on IDB plasma in LHD, for the ablation calculation. Central temperature, $T_e(0)$ and density, $n_e(0)$ are varied in the range of 3 to 13 keV and 2×10^{20} to 2×10^{21}, respectively. Figure 2 shows summary of the pellet penetration depth in FFHR2, FFHR2m1 and FFHR2m2. Error bars in the penetration depth indicate dependence on the density. Dependence of the pellet penetration depths on the temperature is almost same in each case. In other words, the penetration depth hardly depend on machine size, if we choose the same ratio of the pellet size to the given plasma volume. The pellet penetration depth becomes shallow as temperature rise, but the peak of the pellet ablation hardly depend on temperature and it is located in the internal diffusion barrier even at 13 keV.

Diffusion equation is solved to predict density profile change after pellet injection in FFHR2m2, assuming D= 1.0 m^2/s, V= 0 m/s. These particle transport coefficients are estimated by extrapolating LHD experimental result. Figure 3 shows temporal change of the density profile at $T_e(0)$= 11 keV. The pellet particles are locally deposited at IDB just after pellet injection because of shallow penetration, but the central density is kept during density decay phase by inverse density gradient. If the relative large perturbation at the IDB is allowed, pellet fueling is applicable to helical reactor.

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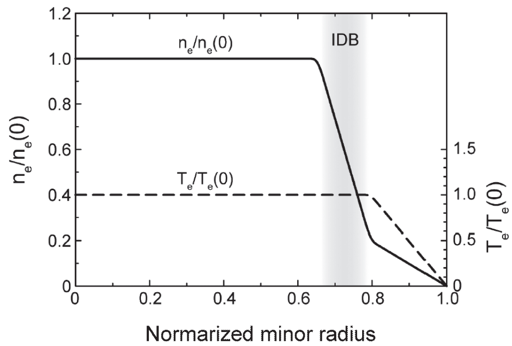

Figure 1 modeled plasma profiles for NGS calculation.

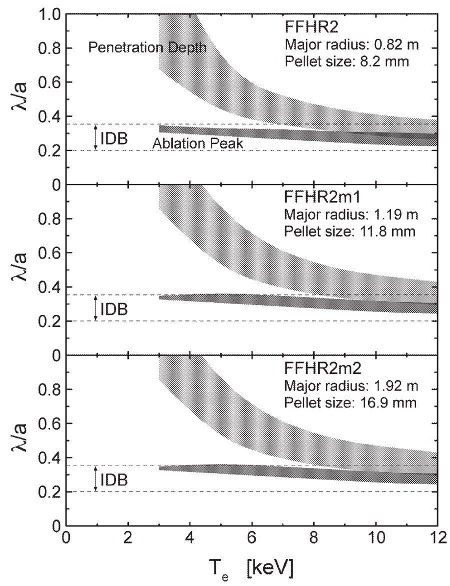

Figure 2 Calculated pellet penetration depth in FFHR2.

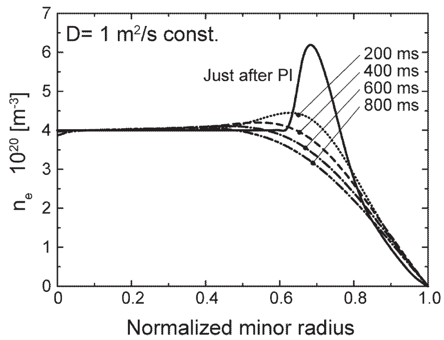

Figure 3 Profile change after pellet injection.