§8. Pellet Refueling Scenario to Allow Self-burning on FFHR-d1

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Pellet refueling conditions to allow self-burning has been investigated by extrapolating confinement property of the LHD plasma to clarify essential requirements for pellet refueling in FFHR-d1. In order to evaluate the self-burning property taking the time evolution of plasma profiles into consideration, the plasma profile evolution was calculated by the combination of the simple particle diffusion equation and the direct profile extrapolation (DPE) method in which the normalized plasma pressure profile obtained from the LHD experiment is directly extrapolated into a burning plasma by assuming gyro-Bohm type parameter dependence. One of the significant improvements from the previous research is a revaluation of the particle diffusion coefficient, which degrades with increasing heating power density. To investigate effects of the pellet penetration depth on the density profile formation and the self-burning property, the pellet velocity is decided so that the pellet penetration depth become preset fixed value. The pellet size is assumed to be about 5 % of the particles in the background plasma, namely, 2×10^{22} atoms in particle number, to suppress the fusion output variation.

Under too shallow pellet penetration conditions below $\lambda/a = 0.3$, the self-burning condition cannot be satisfied due to the insufficient fusion α output as a result of lacking in the core refueling particles. And furthermore, the boundary plasma density easily beyond the density limit in such a shallow pellet refueling conditions. The self-burning solutions are found when the pellet refueling particles are deposited beyond $\lambda/a = 0.3$. Figure 1 shows the pellet penetration depth dependence of the density and temperature profiles at the minimum fusion output to satisfy the self-burning condition. In the case of $\lambda/a = 0.3$, the density profile inside the pellet deposited radius ($\rho < 0.7$) remain nearly unaffected and flat density profile is formed. The density profile become peak as the pellet penetration depth deepens and the peaking factor which is defined by $n_\mathrm{e}(0)/\bar{n}_\mathrm{e}$ become 1.52 at $\lambda/a = 0.9$.

The pellet penetration depth dependence of the self-burning plasma properties under the minimum fusion output conditions are shown in Figure 2. The pellet penetration depth affect to the self-burning plasma properties through the changing plasma profiles and the following tendency are seen as the pellet penetration deepens. (a) Central density increase and central temperature decrease, (b) moderation of the minimum fusion output and increase of the burning rate which is defined as a ratio between the burned particles and fueled particles, (c) suppression of the required fueling rate prolonging the pellet injection interval. It seems reasonable to conclude that the deep pellet fueling allows to moderate the technological difficulties. On the other hand, (d) very high-speed pellet injection beyond 10 km/s, which cannot be attained in present-day injection technology, is required to allow the deep pellet fueling. Although use of larger mass pellet can alleviate the difficulty of high-speed pellet injection, the effect is restricted because the large pellet size may cause unacceptable fusion output variation.

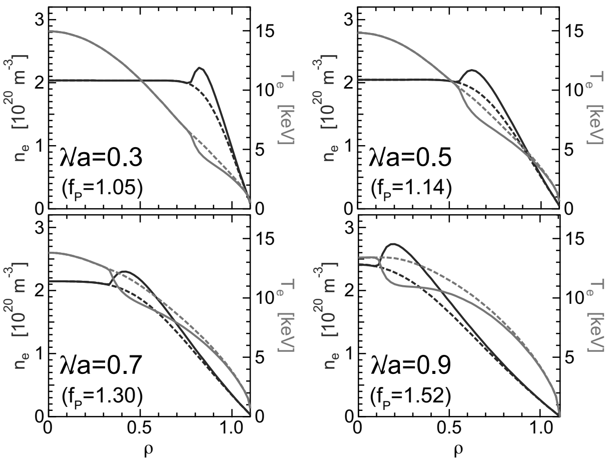

Fig. 1: Density and temperature profiles just before (broken line) and after (solid line) pellet injection.

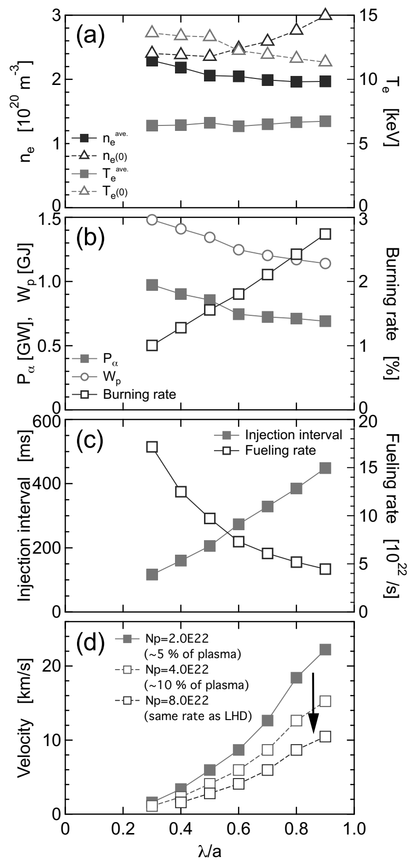

Fig. 2: Dependence of the self-burning plasma parameters on the normalized pellet penetration depth.