§5. Long-Duration Sustainability of Pellet Fueled High Performance Plasma

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For the purpose of investigating fueling issues towards the steady state operation, we have been performed long duration discharge with newly-installed pellet injection timing control system, which is capable of controlling a plasma density in real time.

Fig. 1 shows temporal evolution in a repetitive pellet refueling discharge. Pellets were continuously injected from t= 0.4 s with density control and only pellet injection was employed to build-up plasma density. The reference value of line averaged electron density ($\bar{n}_e$) was set to 0.7×10^{20} m^{-3} during discharge. At the build-up phase (t< 0.2 s), pellet was injected with maximum frequency, 10 Hz. After reaching 0.7×10^{20} m^{-3}, the pellet injection interval has gotten longer (0.6 - 0.7 S) to keep 0.7×10^{20} m^{-3} at the pellet injection timing. The important point to note is that the local measurements at plasma center such as $T_e(0)$, $T_i(0)$ and $n_e(0)$, and the plasma stored energy, W_p are maintained virtually constant in spite of pellet sequence. This quasi-stationary phase can be continued until the end of the neutral beam heating (t= 10.3 s).

The electron density profiles just before and after pellet injection at t=6.158 s and difference between these profiles (Δn_e) are shown in Fig. 2 (a). The pellet is ablated until about half radius and an obvious hollow density profile, which have density peak at ρ= 0.6, is formed just after pellet injection. The hollow profile is gradually relaxed and returns back to the original profile. Even in the density profile relaxation phase after pellet injection, the central density $n_e(0)$ is maintained virtually constant in spite of significant changes of the $n_e(0.6)$ as shown in Fig. 2 (b).

In order to estimate the diffusion coefficient, these density profile change was fitted using following equation.

$$\frac{\partial n}{\partial t} = -\frac{1}{r}\frac{\partial}{\partial r}(r\Gamma) + S = -\frac{1}{r}\frac{\partial}{\partial r}\left(r(-D\frac{\partial n}{\partial r} + nV)\right) + S \approx D\frac{\partial^2 n}{\partial r^2} + \frac{D}{r}\frac{\partial n}{\partial r} + S$$

The assumptions made in the above derivation are that the particle source, S is defined as Δn_e, convection velocity, V is negligible small and diffusion coefficient D is constant in terms of time and radial distribution. Assuming D= 0.05 m^2/s, the calculated density change adequately corresponds with the measurements as shown by solid lines in Fig. 2 (b). Thus we see that the inward diffusion due to inversed density gradient supply particle constantly to the plasma center suppressing a density perturbation in the core region despite a lack of inward pinch velocity. And constant central density; $n_e(0)$ is sustained quasi-stationary during pellet sequence. In these repetitive pellets refueled discharge, a confinement index, which is normalized by International Stellarator Scaling (ISS95), is 1.4 despite the high density operation. The confinement property is equal to peaked density profile plasma, which is transiently attained by deep pellet penetration experiments. However, we should not overlook that the increase of pellet firing interval, which is necessary to keep constant density, due to increase of the density decay time, τ_{decay} after pellet ablation, which is obtained by curve fitting with an exponential function, $C\exp\{-t/\tau_{decay}\}$, as shown in Fig. 3. This tendency is caused by increase of boundary density while keeping constant line averaged electron density during quasi-stationary phase as shown by $n_e(0.9)$ in Fig. 1 and it have liner correlation with neutral density (n_0). Another point to observe is that the plasma stored energy, W_p is gradually continued decline with increasing the boundary density and neutral density. It is speculated that the plasma stored energy, namely, plasma confinement property is respond to neutral pressure through the boundary plasma density.

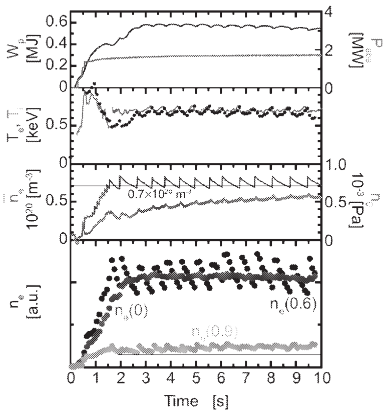

Fig. 1 The temporal evolution of the key parameters in a repetitive pellet refueled discharge. The pellet firing interval is automatically controlled in real time to keep 0.7×10^{20} m^{-3} at the pellet injection timing.

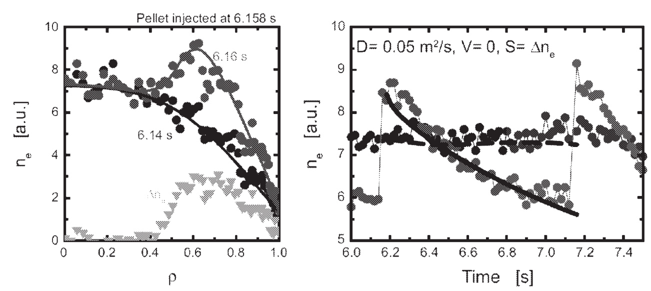

Fig. 2. Comparison between measurement and simple diffusion calculation. The circles and lines denote the measurements and calculation results, respectively. (a)Measured and calculated density profiles change in the density profile relaxation phase after pellet injection. (b)Local electron density evolution at ρ= 0 and ρ= 0.6.

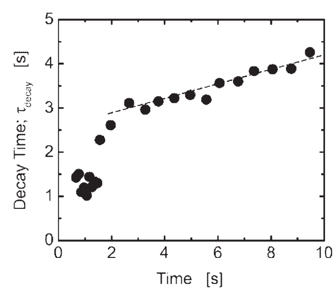

Fig. 3. The change of density decay time in the density profile relaxation phase after pellet injection.