§3. Long-duration Sustainability of Pellet Fueled High Performance Plasma

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High-density operational regime with an internal diffusion barrier (IDB) that enables core plasma to access high-density/high-pressure regime was found in intensive multi pellet fueled high-density discharges on LHD. What seem to be lacking, however, is a scenario of steady state operation, which is absolutely essential in future reactor. If a long-duration sustainability of the pellet fueled high performance plasma is demonstrated, it will offer significant advantage for a fusion reactor. In order to explore the long-duration sustainability of the pellet fueled high performance plasma, long-pulse experiments have been performed by using a couple of different pellet injection (PI) systems. One PI system is a multi-barrel in-situ pipe gun injector which can inject twenty of 3.0 - 3.8 mmϕ pellets at 1200 m/s at a given time. The other PI system is a repetitive pellet injector which can inject 3.0 mmϕ pellet continuously with up to 10 Hz at around 300 m/s. Both injectors have a real-time pellet injection control function by referring to the density related signal such as the line integrated density or bremsstrahlung radiation. Characteristically different point between the two PI is penetration lengths of the injected pellet. The multi barrel pipe gun injector has deep fueling capability due to large mass and high velocity pellet. The pellet typically penetrates to the plasma beyond the magnetic axis in relatively low temperature IDB plasma. On the other hand, the repetitive pellet injector typical can supply the pellet particles outside of a plasma half radius due to lack of the pellet velocity.

Fig. 1 shows waveform of the pellet fueled long-pulse discharges in which IDB plasma is formed by intensive pellet injections at initial phase (t<4 s) and tried to maintain 2×10^{20} m^{-3} by the real-time pellet injection control. In the case of the (a) repetitive PI, the initially formed IDB plasma cannot be sustained due to lack of the core fueling and injection frequency, therefore, the sustainable density decay to 1×10^{20} m^{-3}. The (b) multi-barrel pipe gun PI enable to sustain the set density level during discharge although there is a large perturbation because of direct pellet fueling to the core plasma. Fig. 2 (a) and (c) show effective pellet deposition profiles which are estimated by the density profile difference just before and after pellet injection in the density sustainment phase. Effect of the pellet penetration depth is obvious and almost provided particles are deposited in the outside of the IDB core ($\rho \leq 0.5$) in the case of the repetitive PI. This fact leads to a disappearance of the IDB structure. The initial core plasma density 3×10^{20} m^{-3} with IDB (•) decay to 1×10^{20} m^{-3} in the sustainment phase (×). On the other hand, pellet particles are sufficiently deposited inside IDB core in the case of the multi-barrel pipe gun PI and the initial core density (•) is sustained even in the in the sustainment phase (×) as shown in Fig. 2 (d).

These results suggest that there is no significant inward convection velocity[1)] and the pellet mass deposition characteristics take a substantial role to sustain the IDB profile in LHD. In order to extrapolate the IDB scenario into fusion reactor, it is inevitable to establish an effective core fueling method and to suppress the perturbation which bring severe impact on a fusion output.

1) R. Sakamoto *et al.*, Nuclear Fusion **49** (2009) 085002.

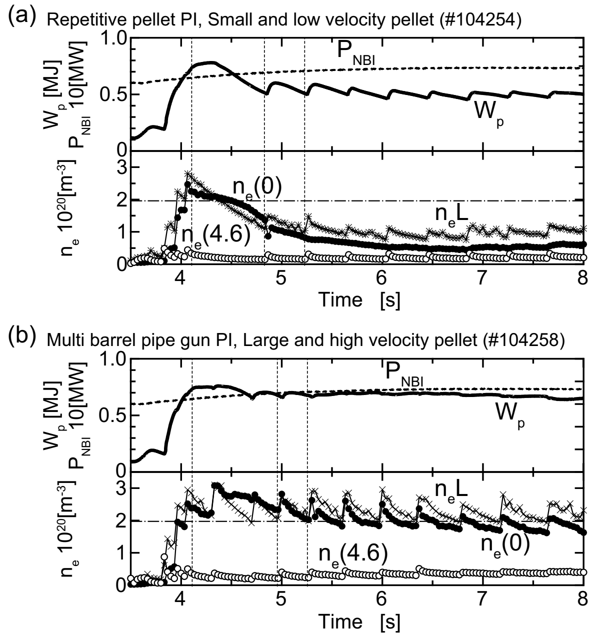

Fig. 1: Temporal changes of the plasma stored energy and densities of the pellet fueled discharges.

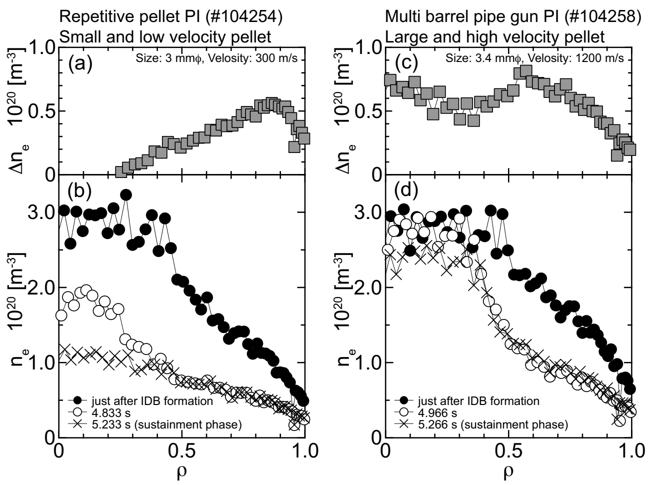

Fig. 2: Effective pellet mass deposition and density profiles at the representative time.