§37. A Low Speed and Small Size Barrel Pellet Injecter in Heliotron J

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It is revealed that the pellet with the size of 0.8 mm and the speed of 300 m/s is required as a main fuelling by a pellet ablation code based on the neutral gas shielding model in Heliotron J, which is a medium sized heliotron device. The injection of the pellet which is a small size and a low speed is technically challenging. However, in this study the pellet injection has been examined by a conventional in-situ technique and a pneumatic acceleration. In the injection barrel, the taper structure is applied for the outlet side to reduce the pellet velocity by the expansion of the propellant gas and for the inlet side to force the pellet effectively. The pellet injection system has been successfully installed in Heliotron J. The intact pellets with the size of 0.8 mm at the velocity of 270 m/s are confirmed by shadow graph and light gate measurements.

The various techniques are applied for a main fueling in the magnetic fusion devices. The pellet injection is one of the most efficient techniques for a core fueling. In tokamaks, the electron density over the Greenwald limit has been attained by the pellet injection. In a helical system, super dense core plasma with the electron density over 10^{21} m^{-3} is attained in LHD by the pellet injection. In the past, the pellet injection was also applied in the medium sized fusion devices such as Heliotron E. However, it is a technically challenging because the smaller size and the lower speed are required in the pellet, e.g. if the pellet size is larger, the perturbation on the plasma is serious. Also, if the pellet speed is higher, the penetration to the plasma is too deep and then the proper fueling cannot be expected. In TJ-II, the pellet injection system developed by Oak Ridge National Laboratory has been installed to inject the small pellet less than 1.0 mm, although the speed is high at 1000 m/s. So far, the Hα emission by the pellet ablation has been observed, and the pellet injection for the high density plasma is expected in futre. The objective of this study is to develop the injection system of the small size and low speed pellet for Heliotron J device. Heliotron J is a helical-axis heliotron device with an L/M = 1/4 helical coil based on the helical-axis heliotron concept. Here L and M are the pole number of the helical coil and its helical pith number. The major radius is 1.2 m and minor radius is 0.15 m. The maximum magnetic field strength is 1.5 T. In Heliotron J, the optimization of gas fueling scenarios has been studied to improve the plasma performance. The electron and ion temperatures in the super molecular-beam injection (SMBI) is observed to be higher than that in a conventional piezo valve. Also, a peaked density profile is observed after SMBI. These observations point out the importance of SMBI fueling for plasma density control to obtain better plasma performance, suggesting that core fueling is efficient for the high performance plasma. Moreover, a robust NBI system compatible with the pellet injection is provided and potentially high performance plasma by the pellet injection could be expected. That is the motivation for attempting the pellet injection in Heliotron J.

The pellet injection system has been installed in Heliotron J, as shown in Fig. 1. The injection barrel has a specific structure. The tube with the inner diameter of 0.8 mm is needed in the barrel. However, it is considered to be difficult to obtain the strength enough to maintain itself. Also, there is a technical problem of the blazing between the thin cupper and the minute stainless steel. Therefore, we propose the barrel manufactured by the hot isostatic pressing material of cupper and stainless steel. Also, to reduce the pellet speed, the taper structure is applied to dissipate the force by the propellant gas in the outlet side. Moreover, the taper structure is applied also in the inlet side in order to propagate the propellant gas efficiently. The injector is equipped with a light gate system to measure the pellet speed by a time of flight measurement between two fixed positions. Each light gate consists of a laser and a photodiode. A shadowgraph system consisting of a CCD camera and a flash lamp of 180 ns pulse width is installed on the second chamber to confirm the intactness of the pellet. An intact pellet size of ~ 0.8 mm has been confirmed from the shadow-graphic image as shown in Figure 2. The effect of the taper structure is confirmed. The pellet speed measured by the lightgate systems is 270 m/s, which is close to the assumption at the barrel length of 1 mm. The acceleration pressure is 2.0 MPa and the temperature is 6.8 K. In the next experimental campaign, the pellet will be injected into the plasma for the first time in Heliotron J.

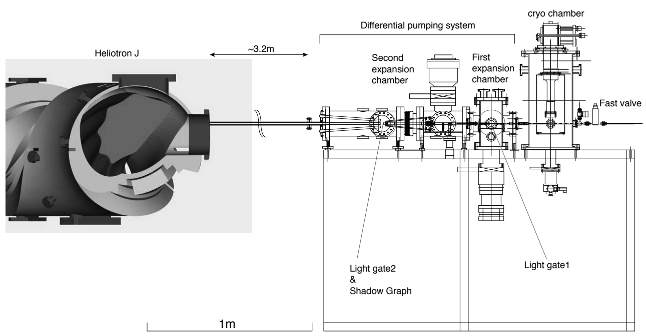

Fig. 1. Schematic view of the pellet injection system in Heliotron J.

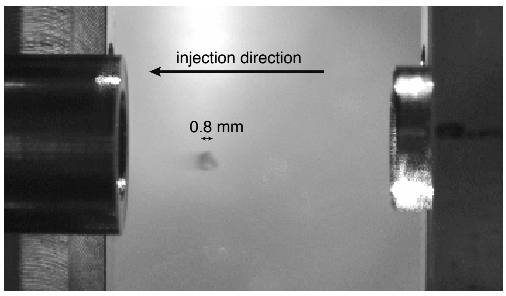

Fig. 2. The graphic view of the pellet measured by the shadow graph.