§21. Study of Pellet Injection for Efficient Core Plasma Fuelling in Heliotron J

Motojima, G., Sakamoto, R., Mizuuchi, T., Okada, H., Murakami, A. (Grad. Univ. Advanced Studies), Ohyabu, N., Nakamura, Y. (Kyoto Univ.), Yamada, H., Sano, F. (Kyoto Univ.)

In the pellet injection system which utilizes pneumatic acceleration, the differential pumping system is required to prevent the propellant gas (e.g. He) from flowing into the plasma vacuum vessel. As for the hardware, the size of the pellet injection system is mainly occupied by the differential pumping system. In this study, the performance of the two-stage differential pumping stages is investigated in order to approximate the size of the pellet injection system in Heliotron J device.

The performance of the pumping system is estimated by the following equations;

$$\begin{cases} V_1 \dfrac{dP_1}{dt} = I_{acc} + C_{12}(P_2 - P_1) - S_1 P_1 + L_1, \\ V_2 \dfrac{dP_2}{dt} = C_{12}(P_1 - P_2) + C_{23}(P_3 - P_2) - S_2 P_2 + L_2, \\ V_3 \dfrac{dP_3}{dt} = C_{23}(P_2 - P_3) - S_3 P_3 + L_3, \end{cases}$$

where, $I_{\rm acc}$, P_i, V_i, S_i, C_i and L_i represent the propellant gas inflow rate, pressure of the stage i ($i = 3$ denotes the vacuum vessel), volume of the stage i, pumping capacity of the stage i, conductance between the stages i and $i+1$, and leak and/or degassing rate of the stage i, respectively. The volume of the chamber is assumed to be in the range between 0.01 and 0.04 m^3. Figure 1 shows propellant gas entry into the vacuum vessel. Here, in the above equations, the following parameters are given.

$$\begin{cases} V_1 = V_2, V_3 = 2.1\ \mathrm{m}^3, I_{acc} = 2.5\ \mathrm{Pam}^3@t = 0 \\ C_{12} = C_{23} = 1.4 \times 10^{-4}\ \mathrm{m}^3\mathrm{s}^{-1} \\ S_1 = S_2 = 0.15\ \mathrm{m}^3\mathrm{s}^{-1}, S_3 = 2.7\ \mathrm{m}^3\mathrm{s}^{-1} \\ L_1 = L_2 = 1.5 \times 10^{-6}\ \mathrm{Pam}^3\mathrm{s}^{-1}, \\ L_3 = 2.7 \times 10^{-5}\ \mathrm{Pam}^3\mathrm{s}^{-1} \end{cases}$$

The propellant gas entry is decreased with the increase of the volume of the chamber. Since the entry amount in any case of the volume of chamber between 0.01 and 0.04 m^3 is much less than the pellet particles (2×10^{19} atoms) of 0.8 mm size which is required in Heliotron J, the volume of chamber with 0.01 m^3 seems to be enough.

Here, we propose the use of the differential pumping system used in punch mechanism-based low speed pellet injector in LHD (see Fig. 2). The volume of the chamber in the punch pellet injector is $V_1 = 0.015\ \mathrm{m}^3, V_2 = 0.02\ \mathrm{m}^3$, which are enough from the point of the propellant gas entry as shown above discussion. The pumping capacity is also similar or more than the estimation in this study. The utilization of the differential pumping system in the punch pellet injector enables the early install of the pellet injection system in Heliotron J.

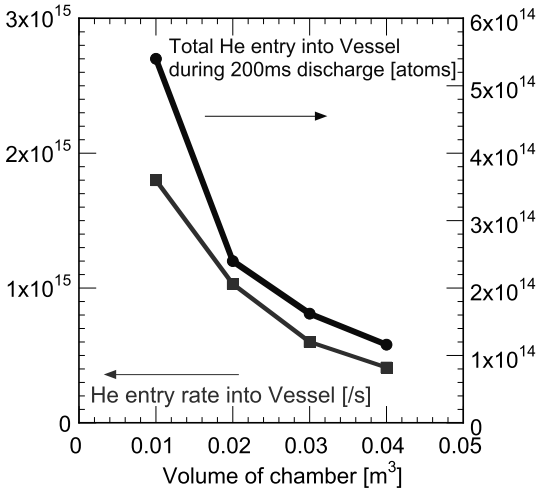

Fig. 1: Dependence of propellant gas entry into the vacuum vessel on the volume of chamber.

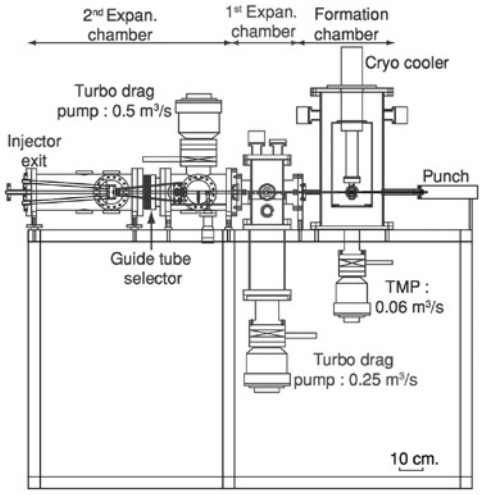

Fig. 2: Punch mechanism-based low speed pellet injector in LHD[1)].

1) J.S. Mishra et al., Rev. Sci. Instrum. **82** (2011) 023505.