§36. Fueling Pellet Injector for LHD

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A fueling pellet injector will be installed in the second campaign of LHD experiment. Design concept of this pellet injector consists in high reliability and maintenance free. It is possible to operate remotely and continuously from control room.

Since hydrogen ice pellet injection enables to refuel directly to core plasma region, the fueling efficiency is higher than a neutral gas fueling. There are several methods of the pellet formation and propellant. Conventional pneumatic pipe gun type pellet injector is adopted as the pellet injector for LHD. In pneumatic pipe gun type pellet injector, fuel gas (H_2, D_2) is admitted into forming part of gun barrel that is maintained below the triple point temperature of the fuel. The fuel is frozen there, forming an ice pellet. Then the pellet is accelerated using the expansion of compressed gas (He, H_2) in the barrel. Since there is no movable part at low temperature, this type pellet injector is simple in construction. Then the device is highly reliable and stable. However, it is impossible to perform multiple pellet injection by single barrel, because it takes few minutes to prepare the next pellet. Multiple barrels are required to perform multiple pellet injection.

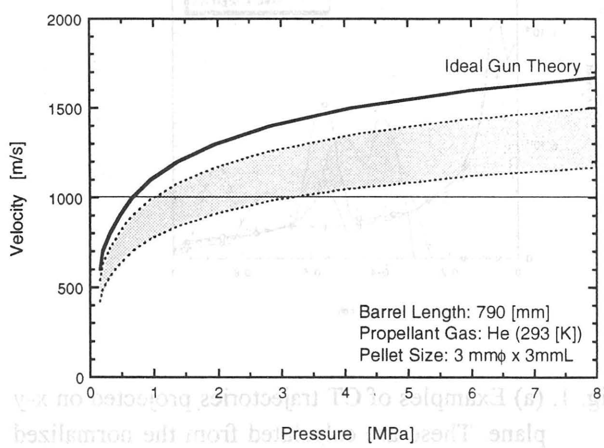

Fig. 1 Hydrogen ice pellet velocity dependence on propellant gas pressure.

At the startup phase, the single barrel will be installed. The pellet shape is cylinder with diameter of 3 mm. The ratio of length to diameter can be change in the region of 1 – 1.6, therefore the feed particle can be estimated to be about 1.1 x 10^{21} – 1.8 x 10^{21} particles per pellet. Finally, the barrel will be increased up to 10. Then the pellet size is available for 1.5 mm, 2.0 mm, 3.0 mm and 3.8 mm diameter, which feeds 1.4 x 10^{20} – 3.7 x 10^{21} particles per pellet to LHD plasma.

When applying the model of expansion of ideal gas to propellant of pellet (ideal gun theory), behavior of pellet injection can be expressed as follows,

$$V = \frac{2C_0}{\gamma - 1}\left(1 - \left(\frac{\tau}{t_{acc} + \tau}\right)^{\frac{\gamma-1}{\gamma+1}}\right), \qquad (1)$$

$$L = \frac{2C_0}{\gamma - 1}\tau\left(\frac{t_{acc}}{\tau} - \frac{\gamma+1}{2}\left(\left(1 + \frac{t_{acc}}{\tau}\right)^{\frac{2}{\gamma+1}} - 1\right)\right), \qquad (2)$$

Where V is the velocity, C_0 is the acoustic velocity of the propellant gas, T is the temperature of the propellant gas, P_0 is the initial pressure of the propellant gas, γ is the specific heat ratio of the propellant gas, ρ is the density of the pellet, l_p is the length of the pellet and τ is the time constant ($=2\, C_0 \rho\, l_p / (\gamma + 1)\, P_0$).

Fig.1 shows the plot of the pellet velocity versus pressure of the propellant gas (solid line), that obtains by solving the above simultaneous equations using the device parameter. The hatching region shows 70 – 90 % of the calculated value, that the value shows the predicted velocity for the actual device. As seen from this plot, it is possible to achieve velocity of more than 1 km/s, when it is accelerated by propellant gas pressure of more than 3.5 MPa.

In the pellet injector, several measurement devices will be installed in order to identify the pellet property. The velocity of the pellet will be determined by time of fright. The pellet mass will be determined by the output of reflected wave from the microwave cavity at the time of pellet passage the cavity. A pair of laser (or first flash lamp) – CCD camera will be set up at an exit part of the guide tube in order to take a shadow graph. It is possible to know pellet size and soundness by using the shadow graph.