§3. Optimization of Fueling in Magnetically Confined Plasmas ~Analysis of Neutral Behavior and Optimization of Particle Fueling in Open Magnetic Field Plasmas~

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In magnetically confined plasmas, optimization of particle fueling is an important subject to achieve high performance plasmas. In GAMMA10 tandem mirror, supersonic molecular beam injection (SMBI) has been demonstrated as a new particle fueling method to produce high density plasmas. In this FY, we have tried gas fueling by SMBI with newly equipped Laval nozzle[1]. The snapshot of the Laval nozzle is shown in Fig. 1. Prior to the experiment, the magnetic shielding vessel for the SMBI valve has been modified and improved to prevent the effect of the external magnetic field to the operation of the valve. The SMBI valve was installed at the midplane of the central cell.

The response of the gas fueling by SMBI to the electron density was investigated by changing the SMBI plenum pressure. Figure 2 shows the time evolution of the line-integrated electron density at the central cell (NLcc). The plasma was heated only by ICRF and the target plasma density before SMBI was 1.4×10^{18} m^{-3}. The pulse width of SMBI was 0.5 ms and the plenum pressure was from 0.5 to 2 MPa. In the case of the plenum pressure at 2MPa, the increase in NLcc was almost doubled, while a strong decrease in the stored energy was found. This is due to the increase in the CX loss of the hot ions produced by ICRF. Then the optimization of the heating/fueling scenarios is required so as to reduce the CX loss.

The relation between the increase in NLcc (ΔNLcc) and the H$_\alpha$-line emission intensity ($\Delta I_{H\alpha}$) by SMBI is plotted in Fig. 3(a). Since both ΔNLcc and $\Delta I_{H\alpha}$ increase to the plenum pressure, the particle fueling rate by SMBI is proportional to the plenum pressure in this operation range. The directivity of the gas fueling by SMBI is investigated by the image of fast framing camera. In GAMMA10, a 2 directional image fiber has been installed to observe the H$_\alpha$ emission by gas fueling of SMBI from top and side view simultaneously[2]. The full width at half maximum (FWHM) of the emission profile during SMBI is calculated using the image from the top view and it is an index of the directivity of gas fueling. Figure 3(b) shows FWHM as a function of the plenum pressure and the comparison with the data in the straight nozzle case. In both the case, the directivity decreases up to 1 MPa and is saturated. Since the FWHM value of the Laval nozzle is smaller than that of straight nozzle, the directivity of Laval nozzle is better.

In summary, by means of installing the new Laval nozzle for SMBI, we have obtained the particle fueling with better directivity. The effect of Laval nozzle on fueling efficiency will be discussed using neutral particle transport simulation.

1) Islam M. Md., Nakashima, Y., Kobayashi, S., et al., Proc. 25th Int Toki Conf. (2015), P1-71.
2) Hosoi, K. Doctoral Thesis, Tsukuba (2014).

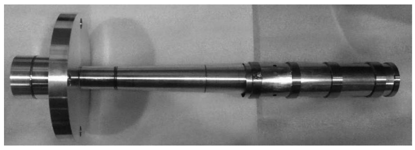

Fig. 1. Photo of Laval nozzle of SMBI installed in GAMMA10 central cell.

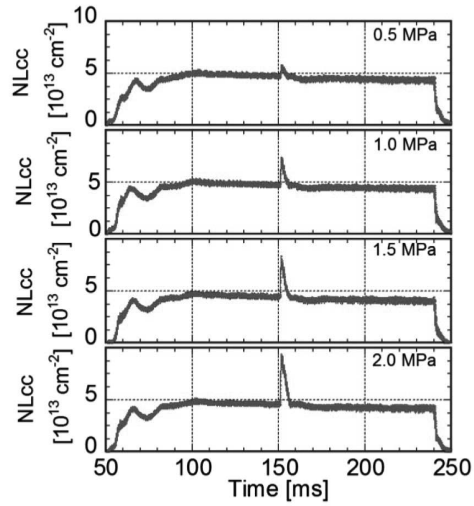

Fig. 2. Time evolution of line-integrated electron density at central cell. SMBI was injected at t=150 ms.

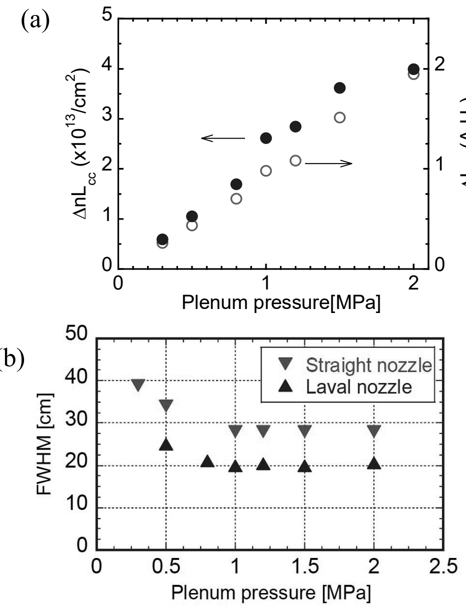

Fig. 3. (a) Increase in NLcc and H$_\alpha$-line emission intensity after SMBI and (b) directivity as a function of plenum pressure of SMBI.