§14. Optimization of Fueling in Magnetically Confined Plasmas (Analysis of Recycling 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[1]. Recently, a straight nozzle was newly mounted on the SMBI valve in order to improve the accessibility of the molecular beam to the plasma[2]. This study reports on the effect of the newly installed nozzle to the fueling.

The SMBI system consists of a fast solenoid valve with a magnetic shield and a straight nozzle. The shape of the straight nozzle is simple cylindrical form made of stainless steel (SUS316). The plenum pressure of SMBI is 0.3 to 2.0 MPa and the pulse width is usually 0.5 ms. A fast camera is used to observe the two sets of the two-dimensional (2-D; i.e., x-z, or y-z) emission image by SMBI using dual branch optical fiber bundles.

A SMBI pulse is injected into ICRF heated plasmas of GAMMA10. Figure 1(a) shows a typical 2-D image captured by the fast camera of visible emission during SMBI. These 2-D images are captured at the timing of the peak emission intensity. To investigate the directivity of the molecular beam injected by SMBI, the axial profile of the neutral transport is investigated based on the 2-D vertical-direction image. The full width at half maximum (FWHM) of the emission intensity at y=0 is calculated as an index of the axial neutral transport. Since the shape of the intensity profile i.e. FWHM is not sensitive to its intensity strength, FWHM at the timing of the peak intensity is used. Figure 2 shows the relationship between FWHM and the plenum pressure of SMBI in two cases, with and without straight nozzle. As shown in Fig. 3, the FWHM value with the straight nozzle is lower than that for the case without nozzle under all plenum pressure condition. Note that the minimum FWHM is about 70% of the plasma diameter. This means that the straight nozzle has a capability to improve the directivity of the particle fueling by SMBI. In the straight nozzle case, the FWHM value decreases with increasing the plenum pressure under the lower pressure (≤ 1MPa) condition, while it saturates above 1 MPa.

A Monte-Carlo simulation is carried out to understand the neutral particle transport during SMBI [1-2]. To simulate the molecular beam by SMBI, we introduce σ_{div} to index the divergence angle of the initial particles. The directivity of the neutral gas is determined from the FWHM value of the Hα emission near the SMBI port. Two kinds of material, "Fe" and "Mirror", are used to model the inner wall of the straight nozzle. As shown in Fig. 3, FWHM for the material of "Fe" was larger as compared with the experimental results, while for the "Mirror" case, the FWHM value in the condition of σ_{div}=0.5 is consistent with the experimental results. Since the neutral gas pressure inside the straight nozzle is expected to be high, neutral-neutral collision effects may affects the neutral transport inside the nozzle. Although the further analysis is required, the simulation result for the case of "Mirror" material roughly reproduces the experimental results (see Fig. 1(b)).

1) K. Hosoi, et al., Plasma Fusion Res, **7** 2402126 (2012)
2) K. Hosoi, et al. 9th Int. Conf. Open Magnetic Confinement, August 27th - 31st, 2012, Tsukuba, Japan P-2.

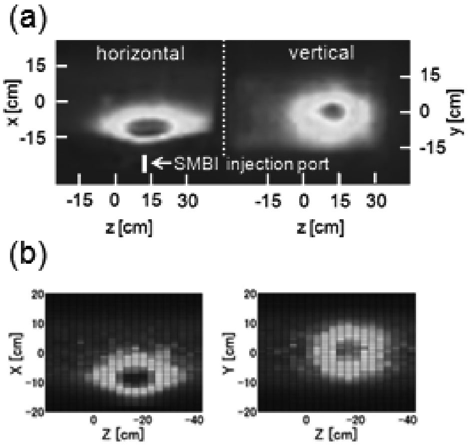

Fig. 1. (a) Fast camera image of the visible emission during SMBI and (b) 2-D Hα image calculated by simulation.

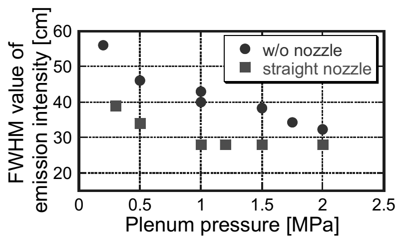

Fig. 2. FWHM of emission intensity from camera image as a function of plenum pressure.

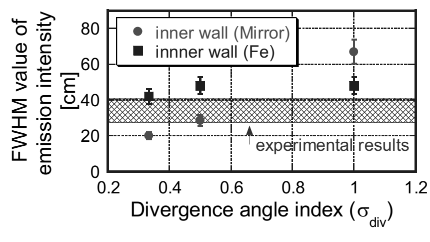

Fig. 3. FWHM of emission intensity by simulation as a function of divergence angle index.