§8. Measurement and Control of a High-Mach-Number Plasma Flow

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Production of a high-beta, supersonic plasma flow with a magnetic field is quite important for basic researches on MHD phenomena in space and fusion plasmas. A magneto-plasma-dynamic arcjet (MPDA) is one of the promising devices to produce a supersonic plasma flow and is utilized as an electric propulsion with a higher specific impulse and larger thrust.

Plasma flow velocity of the MPDA is expected to increase by applying an external divergent magnetic nozzle which converts a high ion thermal energy to an axial flow energy. In a divergent magnetic nozzle configuration, a supersonic plasma flow with ion acoustic Mach number, M_i, up to 3 has been successfully obtained in the far downstream region of the MPDA. In a uniform axial magnetic field configuration, on the other hand, the Mach number is limited at the value near unity [1]. From spectroscopic measurements in the vicinity of the MPDA muzzle it is found that both axial and rotational flow velocities increase linearly with the increase of discharge current, but, at the same time, ion temperature increases more steeply, resulting in the limitation of M_i less than unity in the vicinity of the muzzle [2].

To realize a supersonic plasma flow with more higher M_i, it is very important to develop an optimum magnetic nozzle configuration in the vicinity of the MPDA muzzle. A small-sized coil with a stronger field is attached near the MPDA muzzle to form a Laval-type magnetic nozzle configuration. The subsonic flow near the muzzle is expected to be supersonic through the magnetic Laval nozzle, as is in a conventional compressible gas flow. As shown in Fig.1, it is found that the ion Mach number increases from 1 to 1.5 by the addition of the small magnetic Laval nozzle. With the nozzle magnetic field attached, the ratio, $J_{\parallel}/J_{\perp}$, which is proportional to M_i, increases at a higher discharge current I_d , though without the attached nozzle field it tends to saturate as shown in Fig.2.

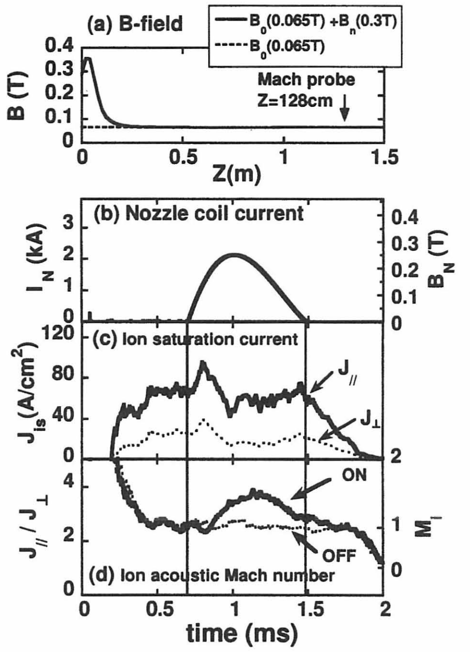

Fig. 1. Axial profiles of (a) B_0 and B_N, (b) I_N, (c) $J_{\parallel}$ and $J_{\perp}$ and (d)M_i. $I_d = 8.2kA$.

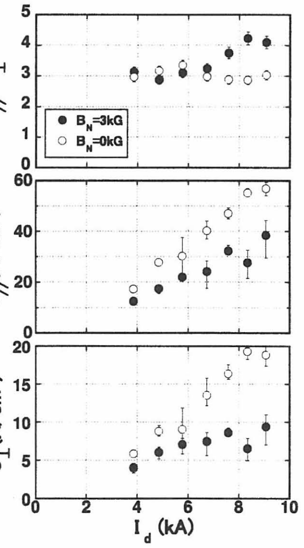

Fig. 2. (a) $J_{\parallel}$ / $J_{\perp}$, (b) $J_{\parallel}$, (c) $J_{\perp}$ as a function of I_d.

References

1) Inutake, M. *et.al.*: Proc. of 10th ICPP2000 (Quebec) **1**, (2000) 148.
2) Ando, A. *et.al.*: J. Plasma Fusion Res. SERIES, **4**, (2001) 373.