§9. Formation of Electric Field in a Fast-flowing Plasma with Diverging Magnetic Nozzle

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Recently, the production and control of a fast-flowing plasma is of growing significance. Formation of an electric field and electromagnetic force appeared in the plasma flow strongly influence various MHD phenomena observed in space and fusion plasmas and characteristics in advanced electric propulsion systems. Magnetic nozzle acceleration in a fast-flowing plasma attracts much attention as a new control method of flow energy in various applications[1)].

A fast-flowing plasma with M_i~1 is generated by using a Magneto-Plasma-Dynamic Arcjet (MPDA) which is attached at the HITOP device. [1)] Various profiles of an axial magnetic field up to 0.1T can be generated by large external coils. Two solenoid coils (a diverging magnetic coil and a Laval nozzle coil) are set near the thruster exit to superimpose various strength of a magnetic diverging field and the magnetic Laval nozzle. The magnetic field strength is given by the sum of the uniform field B_0, the diverging magnetic field B_{zc}, and the magnetic Laval nozzle B_{zL}. Figure 1 shows the magnetic Laval nozzle configurations applied to an MPDA.

Figure 2 shows that the dependence of observed thrust on the magnetic Laval nozzle field strength. The thrust increases with the magnetic Laval nozzle strength. We investigated the flow velocity and ion temperatures by using optical emission spectroscopy. The results show that flow velocity increases and ion temperature decreases by the effect of the magnetic Laval nozzle configuration.

In order to clarify the effect of electromagnetic force acting in the plasma flow at MPDA muzzle region, temporal variation of magnetic field is measured by3-dementional magnetic loop coils. Current flowing in the plasma is estimated from the measured magnetic field profile, and special distribution of electromagnetic force is obtained. Figure 3 shows that the two-dimensional distributions of axial electromagnetic force F_z at (a) B_{zL}=0 T, (b) B_{zL}=0.15 T. It is shown that the electromagnetic force at the center of the MPDA do not increase by the magnetic Laval nozzle configurations. This result indicates that the aerodynamic acceleration mainly contribute in the magnetic Laval nozzle.

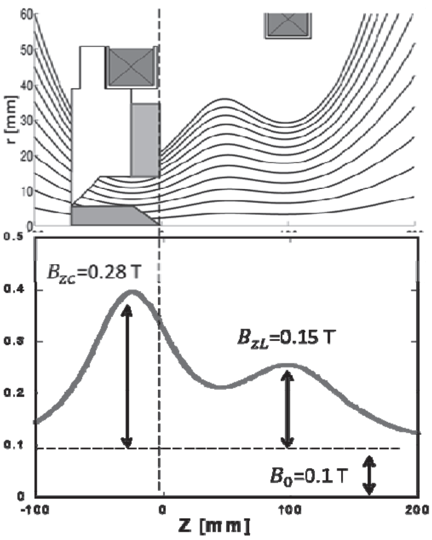

Fig. 1 Magnetic field line and the strength of magnetic Laval nozzle

(1) A. Ando, et al., Trans. JSASS Space Tech Japan, **7**, Pb_35 (2009).
(2) H.Tobari, et al.,Phys. Plasmas, **14**, 093507 (2007) .

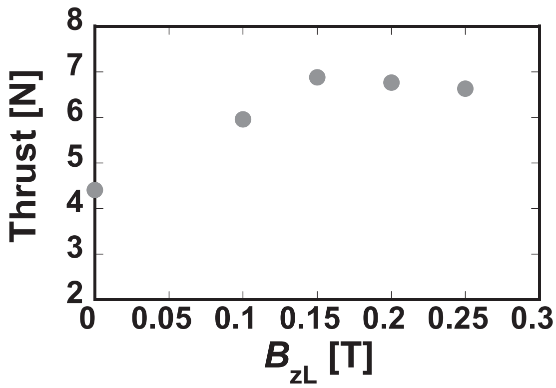

Fig. 2. Dependence of the measured Mach number at z = 160 mm on the magnetic Laval nozzle strength.

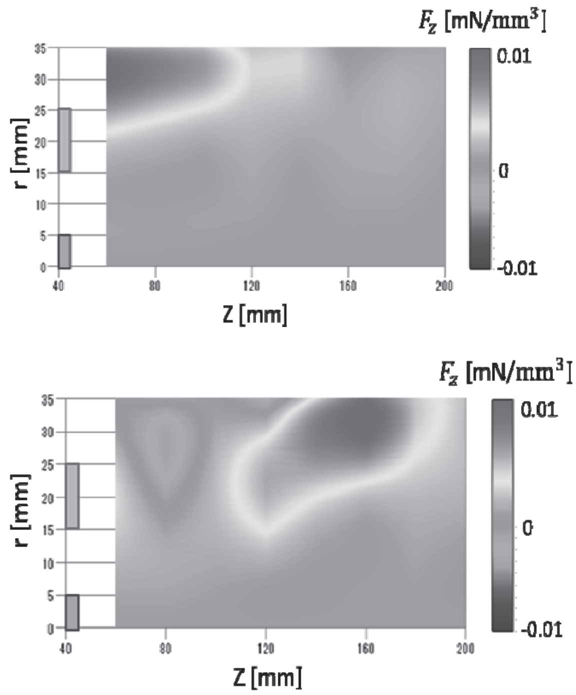

Fig. 3. Two-dimensional distributions of axial electromagnetic force F_z at (a) B_{zL}=0 T, (b) B_{zL}=0.15 T