§11. Plasma Flow Control in a Magnetic Nozzle

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Recently, the production and control of a fast-flowing plasma are of growing significance not only for clarifying various MHD phenomena observed in space and fusion plasmas but for developing advanced electric propulsion systems and applying in various industrial researches.

Magnetic nozzle acceleration in a fast-flowing plasma attracts much attention as a new control method of flow energy in various applications. We have investigated control of supersonic and super-Alfvénic flow by using a magnetic nozzle in the HITOP device.[1),2)]

A fast-flowing plasma with M_i~1 is generated by using a Magneto-Plasma-Dynamic Arcjet (MPDA) shown in Fig.1, which is attached at the HITOP device. [3),4)] Various profiles of an axial magnetic field up to 0.1T can be generated by external coils in the HITOP. An additional small coil was attached on the MPDA in order to form an expanding magnetic nozzle field near the MPDA. Additional magnetic field strength at the coil position B_{zp} was changed up to 0.5T. In plasmas there are azimuthal current I_θ caused by a diamagnetic current and a hall current. Axial force appears I_θ x B_r, where B_r is in a divergent magnetic nozzle. We have investigated the effect of the magnetic nozzle to plasma acceleration.

Figure 2 shows measured thrust and specific impulse as a function of discharge current. The thrust was measured by a pendulum type thrust target. By adding a magnetic nozzle field on the MPDA, these values increased and thrust attains to 8N.

The exhausted plasma flow velocity and ion temperature were measured by a spectrometer at downstream of the MPDA. Figure 3 shows dependence of plasma flow velocity on magnetic nozzle field intensity at various position downstream. The flow velocity increased with increase of the field intensity, which corresponds well to the increase of the trust. Whereas, the velocity gradually decreased in the downstream region.

Ion temperature was also measured as shown in Fig.4. The temperature increased with adding the magnetic nozzle field. It gradually increased in the downstream region. These behaviors of plasma flow velocity and ion temperature is similar to those of flowing media in expanding tube, where flow energy transfers to thermal energy. It should be investigated more detail in order to control plasma flow with the applied field MPDA.

1) A.Ando, *et.al.*, A. Ando, et al., Trans. JSASS Space Tech Japan, **7** (2009) Pb_35.
2) M. Inutake, *et.al.*, Plasma Phys. Cont. Fusion, **49** (2007) A121.
3) A.Ando, *et.al.*, Transaction of Fusion Science and Technology, **51** (2007) 72.
4) H. Tobari, *et al.*, Physics of plasmas, **14** (2007) 093507.

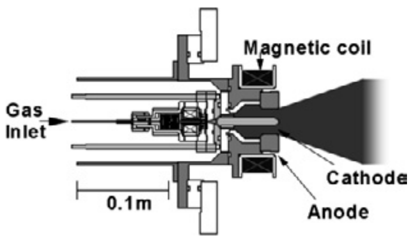

Fig. 1 Schematic of an MPD arcjet

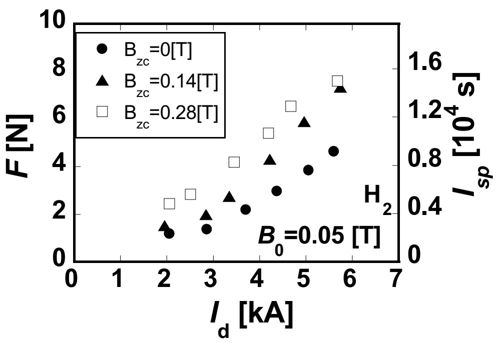

Fig. 2 Dependence of thrust and specific impulse on discharge current with and without magnetic nozzle applied to the MPD outlet.

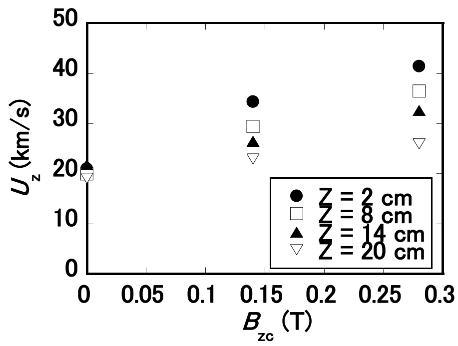

Fig. 3 Dependence of plasma flow velocity on the applied magnetic nozzle field intensity.

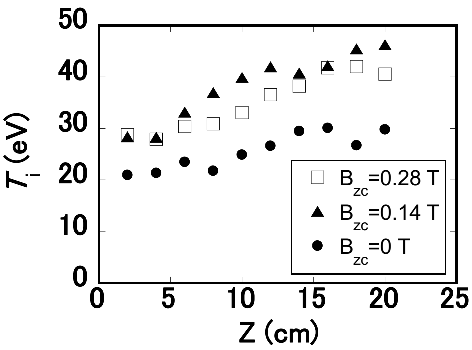

Fig. 4 Axial profiles of ion temperature with various applied magnetic nozzle field intensity.