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Effects of Magnetic Nozzle Configuration on an Applied Field MPD Arcjet
磁場重畳型MPDアークジェットに対する磁気ノズル形状効果

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A Magneto-Plasma-Dynamic arcjet (MPDA) is one of the promising candidates for high power thruster with electric propulsion system. In order to investigate the effect of applied field on a MPDA, we have investigated plume plasma parameters and thrust performance in an applied field MPDA. Different types of divergent magnetic field were applied to a MPDA, and thrust was measured using a pendulum type target. Thrust increased with a discharge current and applied magnetic field. Maximum thrust was obtained when the peak position of applied magnetic field is set at upstream of the MPDA.

1. Introduction

A high-power thruster with higher specific impulse and larger thrust is requisite for manned interplanetary space missions. An electric propulsion system is suitable for long-term mission in space with its higher specific impulse. Magneto-Plasma-Dynamic arcjet (MPDA) is one of the promising candidates for the high power thruster utilizing electric propulsion system. It has been reported that the propulsion performance of a MPDA improves by applying a magnetic field on it [1-3].

When an axial magnetic field is applied on a MPDA, an azimuthal acceleration force appears and rotates the plasma, resulting in an axial acceleration with swirl acceleration. Hall acceleration is also expected by an azimuthal Hall current and radial magnetic field [4]. The azimuthal plasma rotation eliminates current concentration on the electrodes and reduces electrode erosion.

We have conducted experiments of plasma acceleration by applying a divergent magnetic field to a MPDA. When exhausted plasma passed through the divergent field, plasma was accelerated and its Mach number increased. A supersonic and super-Alfvénic plasma was formed in the downstream region of the divergent magnetic field [5-7]. With a divergent magnetic field on a MPDA, electron density and temperature increased.

The thrust force of the applied field MPDA was estimated by measuring the plasma parameters of the flow [8]. We have measured the velocity, density, temperature and spatial profiles of the plasma flow, and calculated thrust from total momentum of the plume plasma.

In order to evaluate the thrust generated in the applied field MPDA, a pendulum type target was fabricated and the thrust was measured. In this paper, we report the effect of applied field on the thrust performance. The intensity and the position of applied magnetic field configuration were changed and its effect on the thrust was investigated.

2. Experimental setup

Experiments were performed in the HITOP device in Tohoku University. The HITOP device consists of a large cylindrical vacuum chamber (diameter D = 0.8 m, Length L = 3.4 m) and external magnetic coils, which can generate a uniform magnetic field up to 0.1 T. A high-power, quasi-steady MPDA is installed at one end of the HITOP device. It has a coaxial structure with a center tungsten cathode rod (10 mm outer diameter) and an annular molybdenum anode (30 mm inner diameter). A quasi-steady discharge continues for 1 msec with a pulse-forming-network (PFN). A fast acting gas valve puffs working gas into the discharge region with the duration of about 3ms. Maximum value of discharge current I_d is 10 kA and a typical discharge voltage V_d is 100 - 200 V depending on the applied field intensity. The MPDA has a small magnetic coil outside of the electrodes and it can apply a strong magnetic field up to 0.5 T.

In this study, the impulse bit ($=F\Delta t$, where F is thrust and Δt is pulse duration of the discharge) was measured by using a pendulum type cylindrical target [9]. The main part of the target was a number of plate disks with a center hole and a bottom cone made of stainless steel (see Fig.1). Plasma plume comes into the cylindrical target through the front plate with an entrance hole of 100 mm in diameter. In order to eliminate the effect of particle reflection on the thrust measurement, a number of disk plates formed a many slits around the target. Most of the gas particles reflected from the bottom plate are expected to escape radially from the side slits. When the pulsed plasma flow comes in, the target starts to swing. The swing amplitude depends on the impulse bit. The calibration between the swing amplitude and the impulse bit was performed before the experiment.

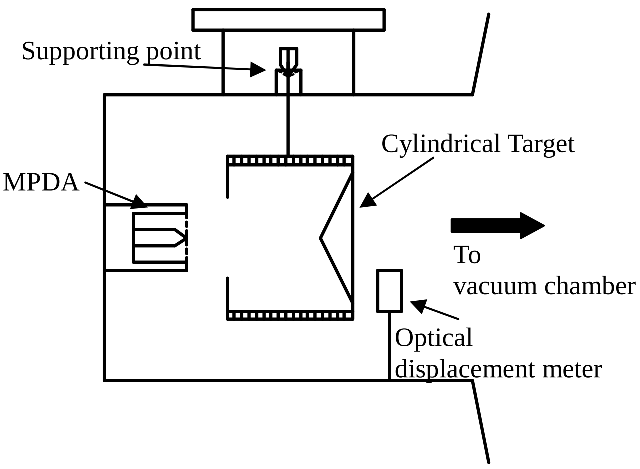

Fig.1. Experimental setup.

3. Experimental results

Various types of applied magnetic field configuration were examined as shown in Fig. 2. Both of a uniform magnetic field (B_0) and an additional magnetic field (B_{zp}) by the small coil attached on the MPDA formed a divergent or convergent-divergent magnetic configuration at the MPDA exit. The peak positions of each magnetic field were set at (a) upstream of MPDA, (b) tip of the cathode and (c) downstream of MPDA.

Figure 3 shows the dependence of thrust measured by the thrust target on the discharge current with the magnetic field of B_0=50 mT and B_{zp}=0.14 T. The working gas was He with mass flow rate of 0.062 g/sec. The thrust increased with the discharge current in each configurations. Larger thrust was obtained when the peak position was set at upstream of the MPDA. We have measured the dependences on the discharge current, magnetic field strength and gas species. The thrust increased with larger magnetic field strength. The thrust and plasma parameters with these three divergent fields were measured and the results will be presented.

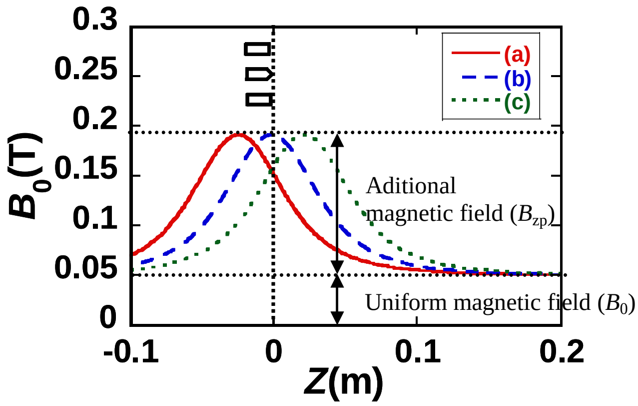

Fig.2. Three types of the magnetic configurations near the MPDA. The peak positions are set at (a) upstream of MPDA, (b) the top of cathode and (c) downstream of MPDA.

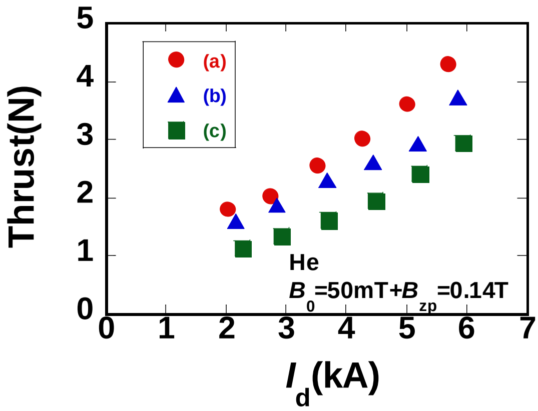

Fig.3. The dependence of thrust on the discharge current with the three types of the magnetic field configurations as shown in Fig.2. B_0=50 mT and B_{zp}=0.14 T.

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