Thrust Performance Of Permanent Magnet Type Helicon Plasma Thruster In Various Magnetic Field Distributions

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In order to realize long-lived electric propulsion systems, we initiated HEAT (Helicon Electrodeless Advanced Thruster) project, and have been investigating various concepts of the electrodeless plasma thruster utilizing helicon plasma source [1, 2]. In these thruster concepts, the entire process of thrust production is conducted without any contact between electrodes and plasma. This electrodeless configuration is one of promising solutions [3] for the problems of erosions and contaminations in conventional electric propulsion systems [4]. In our concept, high-density plasma is accelerated and exhausted by the Lorentz force, which is generated by a diamagnetic current in a diverging magnetic field (magnetic nozzle) [5]. In order to achieve high thrust performance with simple and compact systems utilizing only helicon plasma source, high magnetic flux density magnetic nozzle formed by permanent magnets (PMs) is employed in our laboratory model compact plasma thruster. In this thruster, several types of magnetic field distributions (strength of magnetic flux density, with/without magnetic cusps) can be formed by changing PM‘s assemblage in a magnetic circuit.

Thrust performance of this thruster is investigated by measuring an electromagnetic thrust force using a torsion-pendulum type thrust stand. The electromagnetic thrust force acting on the magnetic circuit is a reaction force from plasma acceleration in the magnetic nozzle, and performance of the magnetic nozzle can be investigated by measuring the electromagnetic thrust force. In the preliminary test of this thruster, electromagnetic thrust force is measured using the magnetic circuit, which has more than 0.2 T of magnetic flux density at the center of the discharge chamber without the magnetic cusp. The electromagnetic thrust force increases with propellant (Ar gas) mass flow rate and plasma production RF power input. Two times thrust jump (drastically thrust increment) is observed by increasing the RF power input. These thrust jumps are probably due to the discharge mode transitions from CCP (Capacitively Coupled Plasma) to ICP (Inductively Coupled Plasma) (the first jump) and ICP to helicon plasma (the second one). Finally 2.3 mN of electromagnetic thrust force is measured when the Ar gas mass flow case of 1.2 mg/s, plasma production frequency and power of 13.56 MHz and 1 kW.

In our next study, thrust characteristics and plasma plume in various magnetic field distributions (lower magnetic flux density case, with magnetic cusp case) will be investigated, and effects of the magnetic field distribution for the thrust performance will be discussed.

[1] Shinohara, S., et. al., *Trans. Fusion Sci. Tech.* **63**, pp 164-167 (2013).
[2] Shinohara, S., et. al., *IEEE Trans. Plasma Sci.* **42**, pp 1245-1254 (2014).
[3] Toki, K., et. al., Int. Elec. Prop. Conf. IEPC-03-0168, 2003.
[4] Anderson, J. R., et. al., Int. Elec. Prop. Conf. IEPC-97-049, 1997.
[5] Nakamura, T., et. al., *World Acad. Sci. Eng. Tech.* **71**, pp 797-801 (2012).