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Preliminary Thrust Measurement in Development of Long Lifetime Helicon Plasma Rockets by Use of Lissajous Method

リサージュ方式によるヘリコンプラズマを用いた
長寿命ロケット開発における推力の予備計測

Takeshi Matsuoka,[1] Syuhei Satoh,[2] Ikkoh Funaki,[1] Takahiro Nakamura,[3] Shunjiro Shinohara,[3] Hiroyuki Nishida,[3] Kenji Yokoi,[3] Timofei S. Rudenko,[4] Konstantin P. Shamrai,[4] Tohru Hada,[5] Takao Tanikawa,[6] and Takayasu Fujino[2]
松岡健之,[1] 佐藤周平,[2] 船木一幸,[1] 中村隆宏,[3] 篠原 俊二郎,[3] 西田 浩之,[3] 横井 賢治,[3] Timofei S. Rundenko,[4] Konstantin P. Shamrai,[4] 羽田 亨,[5] 谷川 隆夫,[6] 藤野貴康[2]

[1]*Japan Aerospace Exploration Agency, Sagamihara, Kanagawa, 252-5210, Japan*
[2]*University of Tsukuba, Tsukuba, Ibaraki, 305-8573, Japan*
[3]*Tokyo University of Agriculture and Technology, Koganei, Tokyo 184-8588, Japan*
[4]*Institute for Nuclear Research, Nauki, Kiev 03680, Ukraine*
[5]*Kyushu University, Kasuga, Fukuoka 816-8580, Japan*
[6]*Tokai University, Hiratsuka, Kanagawa, 259-1292, Japan*
[1]宇宙航空研究開発機構　〒252-5210　相模原市
[2]筑波大学　〒305-8573　つくば市
[3]東京農工大学　〒184-8588　小金井市
[4]Institute for Nuclear Research, Nauki, Kiev 03680, Ukraine
[5]九州大学　〒816-8580　春日市
[6]東海大学　〒259-1292　平塚市

A thrust model for a Lissajous method has shown that a potential of a longer lifetime with competitive performance compared with the rockets using, e.g., ion engines or Hall thrusters. Previous experiments showed a slight increase of plasma flow velocity by this method, however, experimental conditions were not optimized and the thrust was not measured. In this study, in order to develop helicon plasma sources and a thrust measurement method, thermal thrust is measured by using a 26 mm diameter helicon plasma rocket without Lissajous acceleration. A future plan of experiments for verifying the thrust model is also presented.

1. Introduction

For deep space missions, high plasma exhaust velocity (high specific impulse), and a long lifetime are required. Electric propulsion [1] can meet those requirements. Combination of a helicon plasma production and magnetoplasma dynamics acceleration which is powered by radio frequency waves could be a solution because of no physical contact between the plasma and electrodes (electrodeless). Various schemes have been under development to realize electrodeless electric propulsion: VASIMR [2], HDLT [3], and others [4,5].

We have been studying one of the electrodeless thruster, which is called Lissasjous acceleration method [6], whose concept is shown in Fig. 1. This study becomes a part of the HEAT (Helicon Electrodeless Advanced Thrusters) project [7,8]. The thruster consists of two sections, a plasma generation section by helicon plasma discharge and a plasma acceleration section by the Lissajous method. In the acceleration section, rotating electric fields are applied to the plasma in order to excite electron azimuthal currents. The Lorentz force, which is the product of the currents and the static magnetic field produced by the solenoid coil, accelerates plasma and produces thrust.

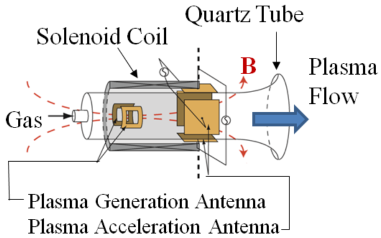

Fig. 1 Concept of Lissajous Method

Plasma acceleration has been observed in experiments. However the exhaust velocity is small compared for practical applications [9]. This indicates that there is a room for improvement by research. Thrust by this method was not measured, and therefore the thruster performance is unknown (exhaust velocity and power efficiency).

In this paper, we report a progress for developments of helicon plasma sources and a thrust stand. The measurements of thermal thrust (thrust due to electron thermal pressure) are conducted in order to clarify tasks for Lissajous thrust measurements.

3. Experimental Results

Experiments are conducted by use of the "Large Helicon Plasma Device" (LHPD) [10] in the Institute of Space and Astronautical Science (ISAS). A quartz tube was placed inside the LHPD. Two inner diameters (I.D.) of 26 and 50 mm are used. Thrust is measured by a pendulum type thrust stand which is placed inside the LHPD. In this experiment, the static magnetic field is applied by the solenoid coils outside of the thrust stand and therefore the electromagnetic thrust is not measured. Details of the experimental set up are reported in Ref. 11.

The first plasma is successfully ignited for 26 mm and 50 mm I.D. tubes. The thermal thrust is shown in Fig. 2 as a function of mass flow rate. The data points in the Fig. 2 are obtained with the I.D. 26 mm tube, the axial magnetic field of 0.008 T and input RF power for plasma generation of 2.1±0.1 kW. The slope of the linear fit curve in the Fig. 2 corresponds to the exhaust velocity of 2.5 km/s. The thrust power efficiency is estimated to be 0.13 %.

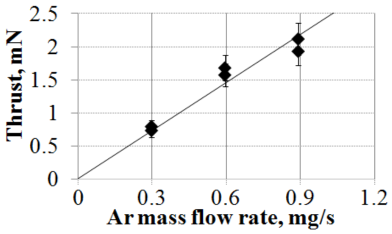

Fig. 2. Thrust as a function of the Ar gas mass flow rate.

4. Future Plan

A laboratory model is fabricated in order to measure Lissajous acceleration by use of permanent magnets. Thrust by the Lissajous acceleration acts on the magnet. Therefore the magnet should be placed on the thrust stand. In order to reduce mass of the thruster, we decided to use permanent magnets instead of a solenoid coil for producing the static magnetic field. It was found that the total mass of the thruster for the I.D. 26 mm tube would be too heavy for the developed pendulum type thrust stand in order to detect thrust by the Lissajous method [11]. Improvement for sensitivity of the thrust stand is under progress.

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5. Summary

Preliminary experiments of thermal thrust measurements from an I.D. 26 mm plasma source are reported. The first plasma is successfully ignited. The developed pendulum type thrust stand is tested by measuring thermal thrust from the plasma source. The thrust is found to be proportional with the mass flow rate. The thrust is 2 mN with 2.1 kW input RF power with exhaust velocity of 2.5 km/s. It is found that the sensitivity of the thrust stand is not enough for detecting thrust by the Lissajous acceleration. Those experimental findings will be used for future experiments for the Lissajous acceleration.

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