Demonstration of Vacuum Arc Thruster with Plasma Interaction Ignition by Nanosatellite

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Abstract: A vacuum arc thruster with plasma interaction ignition has been developed by Kyushu Institute of Technology. The VAT-pi2 used CFRP as a cathode. The negative biased cathode gathered ions from ambient LEO plasma, and the plastic in CFRP is charged positively with respect to carbon fiber. The enhanced electric field in CFRP causes the electrostatic discharge. This discharge initiates the main discharge between anode and cathode. Therefore this VAT does not need any igniters. The VAT-pi2 was mounted on the HORYU-IV nanosatellite, which was launched in February 17, 2016. The mission of VAT was performed.

Nomenclature

\( \text{VAT} \) = vacuum arc thruster

I. Introduction

The CubeSat has a difficulty in mounting thrusters using gas, because of no room in satellite. However, the thruster can allow the CubeSat to perform several missions. In addition, although it was possible to set the rule in the atmosphere within 25 years, it becomes difficult to drop it within 25 years if the altitude is over 600 km at a CubeSat with a high density. Therefore, an orbit descent mechanism is necessary, but by installing a propulsion device, it is possible to lower the orbit. So a vacuum arc thruster, that can be mounted on CubeSat, has been developed. The developed vacuum arc thruster is a pulsed plasma thruster that discharges the electric charge stored in the capacitor between the electrodes and generates a thrust by ejecting the cathode as a jet. The VAT causes the cathode to be more negative than the plasma potential so as to interfere with the plasma in outer space, and causes the main discharge by causing electrostatic discharge. Therefore, in a pulse propulsion such as PPT, it is not necessary to use an igniter to be used for generating a discharge, and it is possible to start a robust and clean discharge. This propulsion is called VAT-pi2 (Vacuum Arc Thruster with plasma interaction ignition). We attempted to demonstrate self ignition discharge in space by installing the VAT-pi2 in the nano-satellite "HORYU-IV".

II. Vacuum arc thruster system

The HORYU-IV was launched in February 2016 with the H2A rocket. The size is about 30 cm cubic and 10 kg. The altitude is 575 km and the orbital inclination angle is 31 degrees. Figure 1 shows the appearance of HORYU-IV. Vacuum arc thruster units are mounted at the locations indicated by VAT. The plume of the VAT is taken by the camera inside the main body by a concave mirror (11. Mirror). A high voltage solar cell (6. High voltage solar array) is also installed, and the VAT-pi2 is driven by electric power generated at about 350 V.

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Figure 2 shows the VAT-pi2 board. The thruster head and capacitor are connected to the PCB board. The capacitor is 10 µF and charged at about 350 V with a high voltage power generation solar cell.

Figure 3 shows a sectional view of the vacuum arc thruster head. The anode can be made of aluminum and the cathode is CFRP. Boron nitride is also used as an insulating material. The anode and the capacitor are connected by a pattern electrode on the PCB board, and the cathode and the capacitor are connected via a cable. By passing this cable through the current measuring coil, the discharge current is measured.

III. Ground validation test

The simulated LEO plasma was generated in the vacuum chamber, and the HORYU-IV system was verified. The discharge current is acquired by an onboard oscilloscope, and arc vision camera takes a image of the plume with this triggered\(^2\). Figure 4 shows the current waveform acquired with the on-board oscilloscope. At the same time, it was confirmed that the waveform was the same as the current waveform measured by the oscilloscope installed outside the vacuum chamber. It was also confirmed that the arc vision camera can measure the discharge plume even if it is a pulse discharge.
IV. On-orbit experiment at HORYU IV

Experimental results on orbit are shown in Fig. 6. The high voltage solar cell generates about 320 V electricity, and it is understood that the temperature rises due to sunlight. Although the generated voltage has been declining in part due to the rotation of the satellite, there are other parts that are falling sharply. Voltage is low even in the place where discharge is detected. As a result, it was possible to confirm the discharge on the orbit. However, at this time the discharge current could not be measured and the discharge emission could not be confirmed.

We will continue to carry out missions aiming at measurement of discharge current and discharge light emission.

V. Conclusion

A vacuum arc thruster with plasma interaction ignition has been developed. A system aiming at on-orbit demonstration at HORYU-IV was also developed. Experimental results on orbit confirmed the discharge due to
interference with the space plasma. We will continue to verify discharge current measurement in space and discharge light emission.

References