2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

# Plume Potential Analysis for Ion Thruster in Ground Test Chamber by a Three-dimensional Electrostatic Full Particle Code

Hiroki Nagai[1] and Takanobu Muranaka[1]
[1] Graduate School of Engineering, Chukyo University
e-mail : t21705m@m.chukyo-u.ac.jp

In recent years, electric propulsion such as ion thrusters, which utilizes the electric energy of an onboard power source for ejecting propellant mass to produce a thrust, are used propulsion device for deep space exploration and control of space systems. For example, "Hayabusa2", a Japanese asteroid explorer, powered by ion thrusters will bring back samples from the asteroid "Ryugu" to help elucidate the origin of the solar system. In operation of ion thrusters, the neutralization of ion thruster is controlled by the equivalent currents from the ion thruster of fast ion beam from the ion source and of thermal electron from the neutralizer. In normal operation of ion thruster, the spacecraft potential is floating and maintained at approximately 0 V due to the balance of the currents emitting from the spacecraft, and the plasma plume with positive potential is formed downstream of the thruster [1]. The difference of potentials between the spacecraft and the plume will accelerate the thermal propellant ions in the plume toward the spacecraft, resulting backflow of the ions onto the spacecraft. These ions impinge the surface of the spacecraft, in fact, Hayabusa2 detected the spacecraft surface erosion around its ion thrusters by the surface contamination sensors [2]. To evaluate the surface erosion, the energy of the backflow should be clarified because the erosion rate is analyzed from the energy [3]. For this purpose, the ground test is ongoing in our research group to measure the energy of the backflow ions because we can hardly detect that in orbit at present. The measurement is made in a large-scale vacuum chamber using the same type of ion thruster mounted on Hayabusa2, but in the chamber, the thruster plume potential could not be the same as that in orbit due to the secondary electrons from the chamber wall generated by the bombardment of the beam ions. In this paper, to clarify the difference of the plume potentials in the vacuum chamber and in space, we numerically reproduce complete neutralization of a virtual small ion thruster by using a three-dimensional full Particle-In-Cell code [4], and evaluate physical process of the neutralization, varying the background condition in the operation of the ion thruster. The numerical results of the neutralization process in the plume and the plume potential are shown mainly with or without secondary electrons in the background.

TABLE I
Computation parameters for complete neutralization of ion thruster

| | |
|---|---|
| ION BEAM | |
| Ion | $Xe^+$ |
| Thruster radius | 0.025 m |
| Accelerating | 1000 V |
| Initial beam current | 0.1 mA |
| Divergence angel | 20 deg |
| Neutralization | |
| Electron temperature | 1 eV |
| Neutralizer radius | 0.025 m |
| Initial beam current | 0.1 mA |
| Numerical Condition | |
| Time step | 1 ns |
| Grid size | 0.005 m |
| Domain size (X*Y*Z) | 512 × 512 × 512 |
| Spacecraft size (X*Y*Z) | 20 × 20 × 20 |

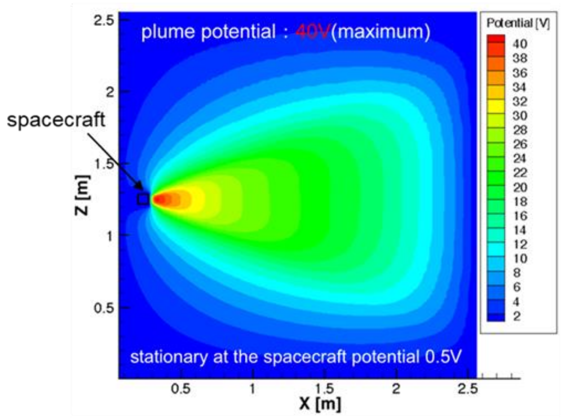


Figure 1 Two-dimensional spatial distributions of the electric potential at 150μs

References
[1] T. Hyakutake et al: DSMC-PIC Analysis of a Plume from MUSES-C Ion Engines, Transactions of the Japan Society for Aeronautical and Space Sciences, vol. 46, no. 151, pp. 24-30, 2003.
[2] K. Nishiyama et al: Operation Status of Ion Engines of Asteroid Explorer Hayabusa2, Proceedings of Space Transportation Symposium., 2017.
[3] Y. Yamamura and Y. Mizuno: Low-Energy Sputterings with the Monte Carlo Program ACAT, IIPJ-AM-40, Inst. Plasma Physics, Nagoya Univ., 1985.
[4] Muranaka et al: Research and Development of Plasma Simulation Tools in JEDI/JAXA, Journal of Space Technology and Science, vol. 25, No. 2, 2011, pp.1-18.