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Evaluation of Contamination on Spacecraft Surface during Operation of Ion Thrusters via Charging Simulation
帯電シミュレーションによるイオンスラスタ作動時における宇宙機汚染量評価

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Rapid increase of spacecraft contamination had measured by HAYABUSA spacecraft after lack of neutralization on its ion thrusters had occurred. It is considered that spacecraft charging due to this had enhanced the contamination by charged particles existing around the spacecraft. A numerical code has been developing to estimate the correlation between the contamination by charged particles and the spacecraft potential. The numerical analysis will clarify the contributions of charged and neutral particles to the contamination measured by HAYABUSA. In this paper, we introduce the present status of the development of the code and result of preliminary charging analysis obtained by using the code.

1. Introduction

Contamination on spacecraft surface is considered to cause degradation of the power generation if it occurs on solar arrays. Therefore, it can determine the spacecraft performance for long-duration mission powered by electric propulsion. In operation of ion thruster, one source of the contamination is outgassing neutral particles from a spacecraft surface exposed in vacuum, and the other is charged particle mostly from plasma plume exhausted by ion thrusters. In Japan, HAYABUSA spacecraft powered by ion engines developed by JAXA had successfully returned to the earth with a small sample of the near-earth asteroid in 2010. During the mission, the contamination on the spacecraft had been measured by the sensors onboard HAYABUSA [1]. The sensors showed rapid increase of the contamination at the time when the lack of neutralization occurred on HAYABUSA’s ion engine system (IES) in November 2009. We consider that spacecraft charging as expected by the ground test [2] must have caused the increase of the contamination by charged particles, and correlation between the contamination and the spacecraft potential can evaluate the contributions of charged and neutral particles to the measured contamination data. To evaluate the correlation between the contamination and the spacecraft potential in ion thruster operation, we upgrade our numerical code for charging analysis and preliminary charging analysis was performed to obtain current-voltage characteristics simulating HAYABUSA with lack of the neutralization.

2. Measurement of Contamination

HAYABUSA was equipped with four ion thrusters, and three of them were simultaniously used in the normal operation. Two contamination sensores (indicated as sensor A and B) adopting a solar arrays [1] had installed onboard HAYABUSA near the exit of one thruster of its IES. We can recognize following two characteristics from the measurement: the degradation of the sensor B increases more than that of the sensor A, and rapid increase of the degradation of the both sensors is recognized during lack of neutralization on the ion thrusters had occurred. The latter is considered due to severe spacecraft charging caused by excess of the emission of the ion beam from the thruster.

3. Numerical Code and Preliminary Simulation

To estimate the contamination obtained by the sensors onboard HAYABUSA, we perform the charging analysis by using HiPIC [3], a three-dimensional electrostatic full-Particle-In-Cell (PIC) code. The code can compute the trajectories of charged particles and electrostatic potential including spacecraft potential selfconsistently. In this work, we have additionaly developed a numerical module to simulate the emission of charged particle beam from a thruster so that we can compute spacecraft charging due to beam [4]. At present, we have performed preliminary simulations to obtaine the current-voltage characteristics between the net current of emitted beam ions and the spacecraft potential. Table I shows the numerical parameters for the simulation. We adopted a cubic conductor of 10 m on each side as a spacecraft model for simplicity. The beam ions we compute are univalent xenon that are emitted in the circular region of its radius being 1 m on the center of one face of the conductor. The monoenergetic beam velocity is determined by the acceleration potential with no divergence angle. The beam current at the spacecraft potential at 0 V is considered to be 10 mA referring the telemetory data for the IES during the lack of the neutralization

Table I. Parameters for Simulation

Size of Spacecraft	1.0 m x 1.0 m x1.0 m
Diameter of Thruster	0.1 m
Beam Ion	Xe^+
Acceleration Potential	900 V
Beam Current	10 mA
Grid Size	0.2 m
Time Step	10 ns

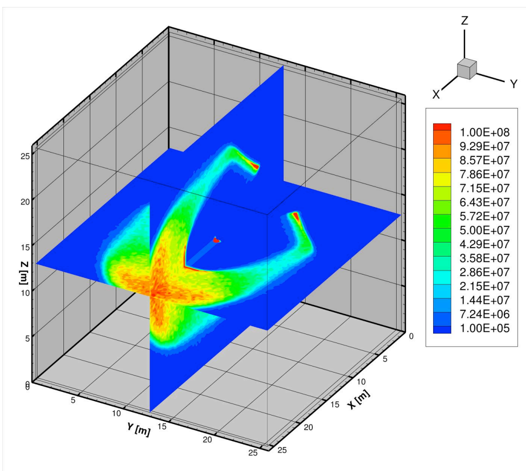

Fig.1. Number density of the beam ions at 0.23 ms obtained by the simulation

had occured. The initial distribution of the beam ions is uniform in space in the circular region. Figure 1 shows snapshot of the number density of the beam ions at 0.23 ms. The small point in the center of the domain indicates the spacecraft model, and the beam ions are emitted from the positive X side of the model. We obtain that the spacecraft potential is of -300 V at 0.25 ms.

4. Conclusion

We have been developing a numerical code to estimate contamination onto a spacecraft caused by charged particles in the operation of ion thruster. Applying the code, we aim to evaluate the correlation between the contamination by charged particles and the spacecraft potential measured by HAYABUSA during lack of the neutralization on its ion thrusters had occurred. At present, we have developed a numerical module to simulate emission of the charged particle beam from an ion thruster, and integrated it to HiPIC solver. A preliminary simulation was made to compute current-voltage characteristics for a spacecraft between the net current of the emitted beam ions. In future, we will include a numerical model of the ionizing process for charge-exchange ions in the thruster plume, and analyze the current-voltage characteristics between currents of beam and charge-exchange ions and spacecraft potential.

Acknowledgments

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