Research on plasma analysis method in electric propulsion

Report Number: R24ECWU04
Subject Category: Cooperative Graduate School System
URL: https://www.jss.jaxa.jp/en/ar/e2024/27350/

Responsible Representative

Yasuhiro Mizobuchi, Aviation Technology Directorate, XANADU Project Team

Contact Information

Kiyoshi Kinefuchi, Department of Aerospace Engineering, Graduate School of Engineering, Nagoya University(kiyoshi.kinefuchi@mae.nagoya-u.ac.jp)

Members

Satoshi Inoue, Masaya Ikuta, Ryohei Takagi

Abstract

The objective of this study is to understand plasma physics phenomena in electric propulsion systems such as hollow cathode and MPD thruster. In order to investigate the distribution of plasma physics inside and outside the electric propulsion, which is difficult to measure in experiments, plasma flow inside and outside the machine is analyzed by numerical simulation.

Reasons and benefits of using JAXA Supercomputer System

By using JSS3, relatively costly calculations can be performed under various conditions when analyzing the flow field in an electric propulsion by the Hybrid-PIC or DSMC methods, because the calculations can be performed at high speed.

Achievements of the Year

Hybrid-PIC simulation of a hollow cathode

When the working gas flow rate is reduced, the hollow cathode becomes a discharge mode that generates unstable discharge oscillations called a plume mode. Because unstable discharges in the hollow cathode cause instability in the entire propulsion system, the boundary between the spot mode, which is a stable discharge, and the plume mode, which is unstable, is the limit of throttling of the hollow cathode. In order to reproduce the transition between the spot mode and the plume mode by numerical analysis, we attempted to calculate the plasma in the hollow cathode at high and low flow rates. The discharge voltage oscillation at 10 sccm is almost negligible, whereas at 4 sccm, when the flow rate is reduced, the voltage oscillation is large. The reason for the larger discharge oscillations at low flow rates is thought to be that the IAT (Ion Acoustic Turbulence) wave due to ion-neutral collisions is less damped as the neutral particle density decreases in the plume region when the flow rate is reduced, resulting in a larger growth of the IAT instability wave.

Hybrid-PIC simulation of a MPD Thruster

In the numerical analysis of MPD thrusters, ions and neutral particles have traditionally been treated as a continuum. However, this approach fails to accurately capture the change in the Larmor radius of ions, which increases sharply with a rapid decrease in magnetic flux density. Therefore, this study adopts the Hybrid-PIC method, in which electrons are treated as a fluid while ions and neutral particles are treated as particles, to conduct the analysis. This year, as a preliminary step toward the analysis of applied field MPD thrusters in the future, we performed simulations without considering magnetic fields. Although the results obtained do not satisfy conservation properties, we have gained certain guidelines for setting the initial computational field.

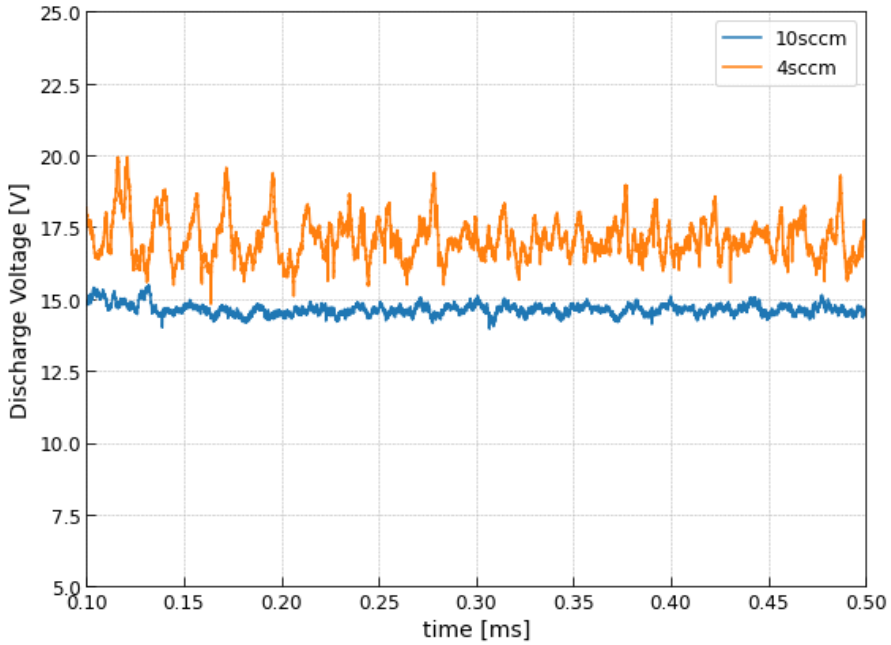

Fig. 1: Discharge oscillation waveform of Hollow cathode

Publications

- Oral Presentations

Ryohei Takagi, Kiyoshi Kinefuchi, Hiroki Watanabe, Sinatora Cho, Kenichi Kubota, Numerical Simulation for Plasma Instability of LaB6 Hollow Cathode, 2024 Space Transportation Symposium, Jan. 2025

- Poster Presentations

Ryohei Takagi, Kiyoshi Kinefuchi, Hiroki Watanabe, Sinatora Cho, Kenichi Kubota, Insert Temperature Measurement and Hybrid-PIC Simulation for Expanding Stable Operating Range of LaB6 Hollow Cathode, The 68th Space Science and Technology Union Conference, Nov. 2024.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	12
Elapsed Time per Case	24 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.04

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	0.00	0.00
TOKI-ST	361,385.24	0.37
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	1,530.00	1.03
/data and /data2	4,900.00	0.02
/ssd	0.00	0.00

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage*2 (%)
ISV Software Licenses (Total)	411.66	0.28

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.