Variation in Ion Acceleration Characteristics of the HERMeS Hall Thruster during Magnetic Optimization

IEPC-2019-713

Companion papers:
902, Wed 15:45
841, Thu 15:00

Wensheng Huang, Hani Kamhawi, and Daniel A. Herman NASA Glenn Research Center
Sep 16, 2019
Presented at 36th International Electric Propulsion Conference

Approved for public release; distribution is unlimited.
Outline

• Introduction
• Magnetic Optimization Test
• Experimental Setup
• Data analysis
• Results
  ▪ Variation in Acceleration Profile
  ▪ Ion Characteristics in Discharge Channel
  ▪ Ion Characteristics near Pole Covers
• Conclusion
Introduction

• A NASA GRC and JPL team developed a 12.5-kW, magnetically-shielded Hall thruster, called Hall Effect Rocket with Magnetic Shielding (HERMeS)

• Flight development continuing in the form of Aerojet Rocketdyne’s Advanced Electric Propulsion System (AEPS)

• Propulsion system for the Power and Propulsion Element (PPE), the first element of NASA’s Gateway

• Completing risk reduction activities (using HERMeS) and transitioning to Engineering Test Unit (ETU) testing

• Developing a related Plasma Diagnostics Package (PDP)
Magnetic Optimization Test

- HERMeS TDU1
  - Throttle range from 0.6 to 12.5 kW, 2000 to 3000 sec
  - Centrally mounted cathode, 7% cathode flow fraction
  - Cathode tied to thruster body
  - Test was in VF6, ~1.2e-5 Torr near thruster

- Four configurations in order of decreasing magnetic shielding: B0, B1, B2, B4
  - B0 is TDU baseline
  - Max radial magnetic field along channel centerline shifted upstream by about the same amount between each configuration in the sequence

<table>
<thead>
<tr>
<th>Label</th>
<th>Discharge voltage, V</th>
<th>Discharge power, kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>300-6.3</td>
<td>300</td>
<td>6.25</td>
</tr>
<tr>
<td>600-12.5</td>
<td>600</td>
<td>12.50</td>
</tr>
</tbody>
</table>
Experimental Setup – Vacuum Side Optics

Additional setup info in AIAA-2018-4723
Data Analysis

- Curve fit-based approach accounting for Zeeman Effect (See paper)
- Spatial uncertainty: 0.5 mm
- Velocity uncertainty: ±112 m/s typical (±600 m/s for noisiest scans)
- On Inner Front Pole Cover (IFPC), two peaks found on axes 2 and 3; comparison to axis 1 shows two ion populations pointed into the IFPC
  - One from the discharge channel, one from the cathode
  - See AIAA-2019-3897 for additional details

600 V, 12.5 kW, around radial middle of the IFPC
Variation in Acceleration Profile

- Noticeable jump in acceleration zone between B1 and B2

![Graph showing variation in acceleration profile](image)

**300 V, 6.3 kW**

**600 V, 12.5 kW**
Prior Modeling Work Points to Possible Cause

- Hall2De simulation from AIAA-2018-4720 shows a different attachment point for the high-energy plasma (red in plots below) for B1 and B2.
- Whereas B0 and B1 were more like magnetically-shielded topology, B2 and B4 were more like reduced / un-shielded topology.

Reproduced from AIAA-2018-4720 for convenience
Ion Characteristics in Discharge Channel

- Going from B1 to B2: Accel zone move upstream, plume becomes less divergent

![Diagram showing ion characteristics in discharge channel](image-url)
Ion Characteristics near IFPC

- Red vectors represent discharge channel stream, blue vectors represent cathode stream.
- Both streams point into the inner pole cover at high oblique angles.

### Data Points

- **300 V, 6.3 kW, B1**: Red vectors at 5 km/s
- **600 V, 12.5 kW, B1**: Blue vectors at 5 km/s
- **300 V, 6.3 kW, B2**: Red vectors at 5 km/s
- **600 V, 12.5 kW, B2**: Blue vectors at 5 km/s
Summary of Ion Energy and Angle near IFPC

- In the labels of these plots, “Cathode” refers to cathode stream, “Discharge” refers to discharge channel stream
- About the same energy and angles across configurations to within uncertainty
Ion Characteristics near OFPC

- **OFPC** = Outer Front Pole Cover
- Energy appear to decrease with configuration but limited number of samples
- Signal to noise ratio was low for conditions with limited samples
Conclusion

• Obtained ion velocity data while shifting the magnetic field upstream

• Observed a large jump in ion characteristics between B1 and B2 that suggest a change in how the plasma interacted with the channel walls and poles

• Ion energies near IFPC were constant to within the measurement uncertainty

• Ion energies near OFPC appeared to decrease as magnetic field shift upstream but data set was limited

• Combined with companion papers (902, Wed 15:45 and 841, Thu 15:00), demonstrate that one can trade pole erosion versus channel wall erosion
Acknowledgment

• We thank,
  ▪ NASA Space Technology Mission Directorate Solar Electric Propulsion Technology Demonstration Mission project for funding this work,
  ▪ Todd A. Tofil, Tiffany M. Morgan, Peter Y. Peterson, Richard R. Hofer and David T. Jacobson for their leadership,

• We also thank our team members:
  Drew M. Ahern Timothy G. Gray Michael McVetta Dale A. Robinson
  Gabriel F. Benavides Thomas W. Haag Ioannis G. Mikellides Timothy R. Sarver-Verhey
  Kevin L. Blake Scott J. Hall James L. Myers Richard G. Senyitko
  Vernon H. Chaplin George P. Jacynycz Derek Patterson Luke Sorrelle
  Maria Choi Nick Lalli Luis R. Pinero George Williams
  Jason Frieman Robert B. Lobbia Richard Polak John T. Yim
  Joshua Gibson Alejandro Lopez Ortega James E. Polk
  James H. Gilland Jonathan A. Mackey Thomas A. Ralys

National Aeronautics and Space Administration

Approved for public release; distribution is unlimited.