The X2 Nested Channel Hall Effect Thruster: an Inner Channel Simulation

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Background

- Hall Effect Thrusters (HETs) have a rich history of over 60 years [1]
- Nested channel HETs were first developed at the University of Michigan in the Plasmadynamics and Electric Propulsion Laboratory (PEPL):
  - ➢ 2 channel, 10kW class X2 by Liang [1]
  - ➢ 3 channel, 100kW class X3 by Florenz [2]

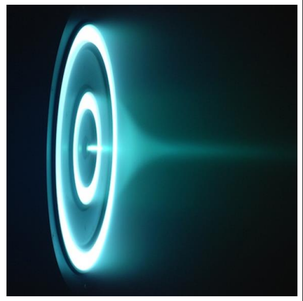
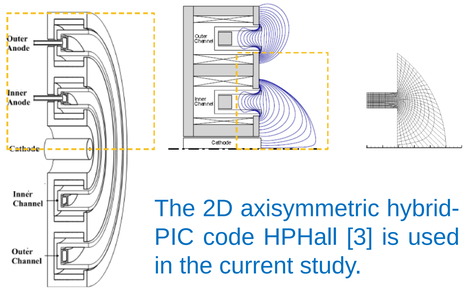


Figure 1: X2 NHT [1].

Simulation Setup



The 2D axisymmetric hybrid-PIC code HPHall [3] is used in the current study.

Parameters:

- Xe propellant
- total number of neutrals: 113,300
- total number of ions: 568,800
- time step: 50 ns
- simulation time: 4 ms
- propellant flow rate: 7 mg/s
- discharge voltage: 200 V
- wall temperature: 812 K
- computation time: 18 hrs

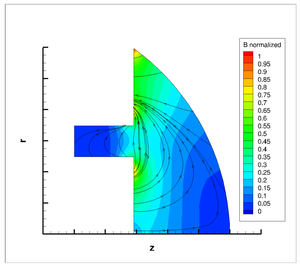


Figure 2: Magnetic field lines.

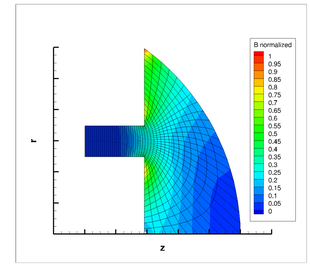
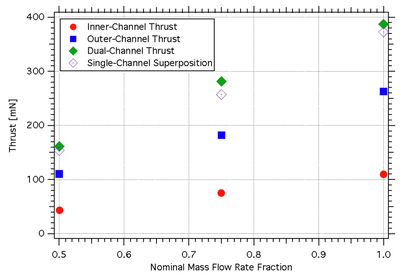


Figure 3: Mesh.

Motivation

Performance gains were observed in multiple channel operation [1]

Table. 1: X2 thrust measurements [1].



- Full characterization of the thruster channels
- Hard to measure quantities inside channel
- Investigation of channel interaction
- Future input for a plume simulation
- Design feedback

Results

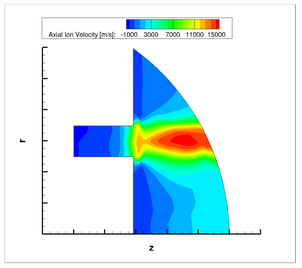


Figure 4: Axial ion velocity

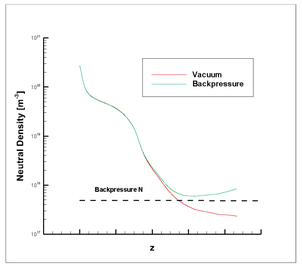


Figure 5: Centerline neutral number density comparison

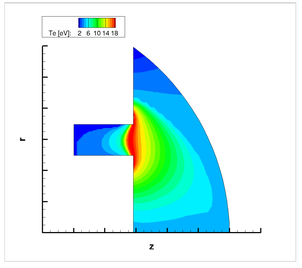


Figure 6: Electron temperature

Thrust Values (mN)		
Measured	Simulation in vacuum	Simulation with $1.5 * 10^{-5}$ $Torr$
92.0 ± 3.00	92.9 ± 0.325	92.7 ± 0.324

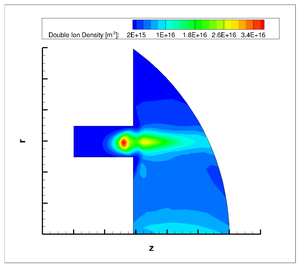


Figure 9: Double ion number density

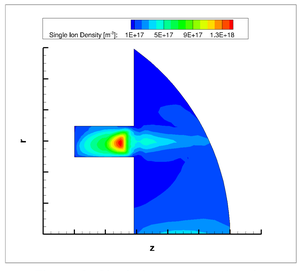


Figure 8: Single ion number density

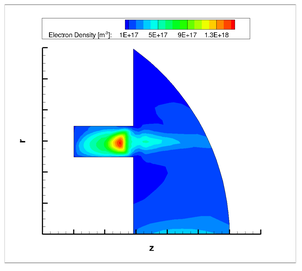


Figure 7: Electron number density

Conclusions

- Facility backpressure does not influence the inner channel
- Thrust values are in good agreement with measurement
- Electron temperature values confirm ionization assumption (no triples)

Future Work

Near term:

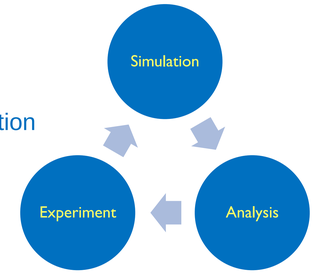
- Obtain raw data for electron temperature and plasma potential measurements, and error bars
- Obtain B field map from measurements and compare to MagNet output
- Obtain B field from Infolytica MagNet for other thruster operating conditions
- Prepare outer channel simulation

Medium term:

- Update code:
  - ➢ Mesh reading routine
  - ➢ Electron model
- Prepare dual channel simulation

Long term:

- Move on to X3 simulations
- Provide design feedback



References

1.Liang, R., "The Combination of Two Concentric Discharge Channels into a Nested Hall-Effect Thruster," Ph.D. Dissertation, Aerospace Engineering Dept., University of Michigan., Ann Arbor, MI, 2013.).
2.Florenz, R.E., "The X3 100-kW Class Nested-Channel Hall Thruster: Motivation, Implementation and Initial Performance," Ph.D. Dissertation, Aerospace Engineering Dept., University of Michigan., Ann Arbor, MI, 2014.).
3.Fife, J.M., "Hybrid-PIC Modeling and Electrostatic Probe Survey of Hall Thrusters," Ph.D. Dissertation, Dept. of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA, 1998.).

Acknowledgments

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