HIIPER Space Propulsion Simulation Using Plasma Module

Z. Chen[1], E. Ziehm[1], G. H. Miley[1]

[1]University of Illinois at Urbana-Champaign, Urbana, IL, USA

Abstract

The Helicon Injected Inertial Plasma Electrostatic Rocket (HIIPER) is an electric space propulsion concept to generate denser ion and electron beams using inertial electrostatic confinement (IEC) fusion theory and helicon source. Helicon source is employed to generate the plasma and the IEC grids are applied to accelerate the particle beam. The advantage of this setup is studied in the previous research [1]. A Langmuir probe [1] is applied to measure the plasma density in the experiment. To verify and better understand the dynamic of plasma density, the 2D axisymmetric COMSOL® simulation performed in the study is a first order inductive coupled plasma (ICP) which coupled with charged particle tracing. To simplify the setup, we use an IEC source to substitute the IEC grids. An image of HIIPER's setup in COMSOL® is shown in Figure 1.

In the experiments, it can be complex and difficult to measure or predict the dynamics of electron density and temperature. To support the experiment and understand the particle behaviors better, simulations in COMSOL® have been performed. These simulations follow largely from previous COMSOL work [2].

In the COMSOL® simulations, we applied plasma module and coupled it with magnetic fields, electromagnetic waves, frequency domain and charged particle tracing. The magnetic field is used to model the coil of the helicon section, the electromagnetic waves, frequency domain is employed to simulate the radio frequency antenna, the plasma module is used to simulate the plasma with argon as a source, and the charged particle tracing model is applied to simulate the ion particle trajectories in the helicon tube and vacuum chamber.

With these simulations, we are able to compare the experimental results with the simulation results and understand the concepts better. The simulation provided the advantage to collect corresponding data from different test cases. Currently, we are able to plot the ion energy distribution function and analyze the radio of ions hitting electrode to losses using COMSOL® simulations.

Altogether, COMSOL® provide a chance to obtain the corresponding data without preform a complex experiment and it supports the experimental results. In addition, COMSOL® simulations allow multiple test cases to be performed in a relatively short time which plays an important role for us to optimize the experimental design.

References

[1] Drew M. Ahern, Hussein Al-Rashdan, Oguzhan Altun, Grant Berland, Emil Broemmelsiek, Zhengyu Chen, Patchara Choakpichitchai, Zongxu Dong, Patrick Drew, Nicklaus Richardson, Nicholas St.Lawrence, Kyle Stanevich, Albert Valiaveedu, and George H. Miley. "Experimental Studies of the Helicon Injected Inertial Plasma Electrostatic Rocket (HIIPER)",

53rd AIAA/SAE/ASEE Joint Propulsion Conference, Atlanta, GA, 2017.
[2]Z. Chen, D. Ahern, G. Miley "HIIPER Space Propulsion Simulation Using AC/DC Module," COMSOL Conference, Boston, MA, Oct. 2017.