Computational Study Of Adding Magnetic Nozzle In HIIPER Using Multiphysics Module

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INTRODUCTION: Helicon Injected Inertial Plasma Electrostatic Rocket (HIIPER) is a two-stage space propulsion system comprising of a helicon plasma injector and an Inertial Electrostatic Confinement (IEC) grid to extract and neutralize the plasma from helicon. Performance advantages of adding a third stage involving magnetic nozzle (MN) is studied using COMSOL.

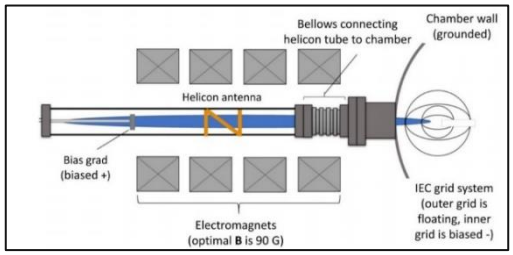

Figure 1. HIIPER Schematic

COMPUTATIONAL METHODS: Numerical studies done involved the following models – magnetic fields (mf), plasma electromagnetic waves and charged particle tracing (cpt). Interparticle effects were not added due to increased computational time and power requirement. The ion parameters were recorded at the end of first stage and input in the next stage to overcome aforementioned issue. Ion flow rate during the simulations was set as 10^{18} $m^{-3}s^{-1}$.

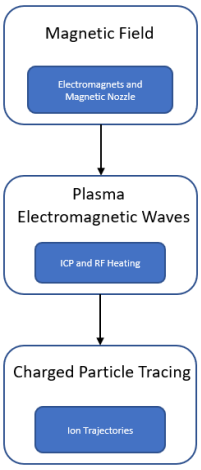

Figure 2. Computational Chart

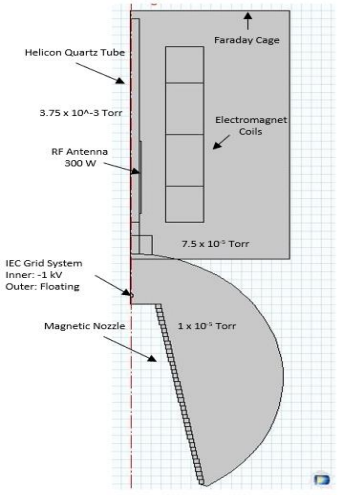

Figure 3. COMSOL Model Diagram

RESULTS: The results depict how the parameters – magnetic flux density, ion velocity, ion force and ion kinetic energy – change with electromagnetic coil current (I_c). It is seen in the plots that higher magnetic field increases the ionic force due to an increase in ion velocities. Estimated experimental values of running HIIPER with I_c = 35 A for 60 seconds should yield, approximately, the following values –

1. Force = 3.8 mN
2. Ionic Velocity = 2 x 10^6 m/s

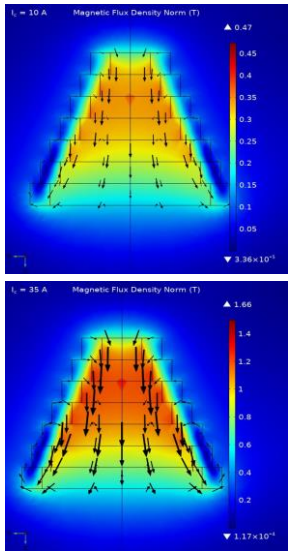

Figure 4: Magnetic Flux Density Norm (a) I_c = 10 A & (b) I_c = 35 A

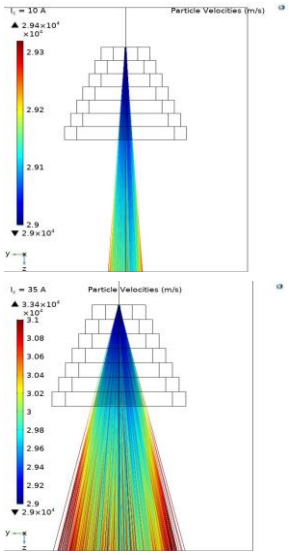

Figure 5: Particle Velocity (a) I_c = 10 A & (b) I_c = 35 A

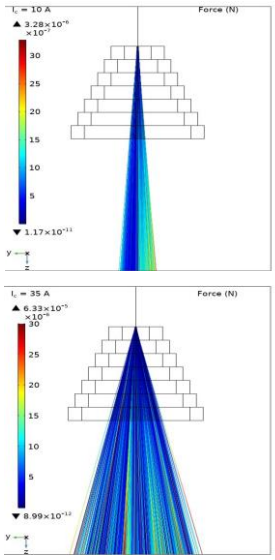

Figure 6: Particle Force (a) I_c = 10 A & (b) I_c = 35 A

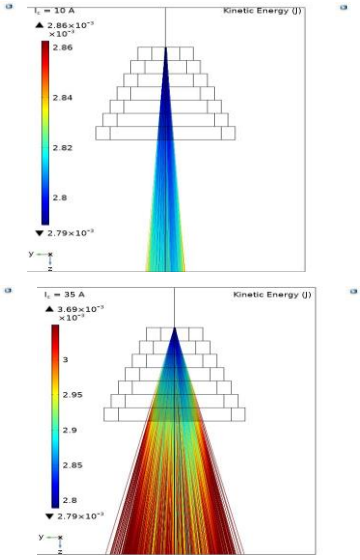

Figure 7: Particle Kinetic Energy (a) I_c = 10 A & (b) I_c = 35 A

CONCLUSIONS: COMSOL simulations made it possible to prove the advantages of having magnetic nozzle in HIIPER. Increase in performance of the propulsion system is expected and preliminary results indicate it to be linearly proportional to the coil current (induced electromagnetic field). Experimental studies will be done to compare with these numerical trends and validate the COMSOL model of HIIPER.

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.