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Author: Dr. Mirko Magarotto
University of Padova - DII/CISAS, Italy, mirko.magarotto@unipd.it

Mr. Simone Di Fede
CISAS – "G. Colombo" Center of Studies and Activities for Space, University of Padova, Italy, simonedifedesdf@gmail.com
Dr. Nabil Souhair
Alma Mater Studiorum - University of Bologna, Italy, nabil.souhair2@unibo.it
Mr. Shaun Andrews
CISAS – "G. Colombo" Center of Studies and Activities for Space, University of Padova, Italy, sa15339@my.bristol.ac.uk
Dr. Marco Manente
T4i, Italy, m.manente@t4innovation.com
Prof. Fabrizio Ponti
Alma Mater Studiorum - University of Bologna, Italy, fabrizio.ponti@unibo.it
Prof. Daniele Pavarin
CISAS – "G. Colombo" Center of Studies and Activities for Space, University of Padova, Italy, daniele.pavarin@unipd.it

NUMERICAL SUITE FOR MAGNETICALLY ENHANCED PLASMA THRUSTERS

Abstract

Over the last few years, several new space systems relying on plasma propulsion have been proposed. One of the most promising technologies are Magnetically Enhanced Plasma Thrusters (MEPTs). The main components are (i) a dielectric tube, inside which plasma is produced, (ii) a radiofrequency (RF) antenna, dedicated to plasma production and heating, and (iii) solenoids or permanent magnets. The latter generates a magnetostatic field which enhances plasma production and improves the thrust via the magnetic nozzle effect. Consequently, the architecture of a MEPT is extremely simple and low-cost. No electrodes in contact with the plasma or neutralisers are needed, so a MEPT is a long-life device that can be easily operated with different propellants. The MEPT will be demonstrated in orbit in Q1 2021, with the REGULUS propulsion unit for CubeSats from Technology for Propulsion and Innovation SpA (T4i).

Despite the simple hardware, the plasma dynamics in a MEPT are non-trivial. The principal phenomena which drive the performance of MEPTs are: (i) Electromagnetic (EM) power deposition in the source, (ii) plasma generation and heating, and (iii) conversion of plasma thermal energy into acceleration by means of the magnetic nozzle. Although semi-analytical models have been developed to estimate the performance of MEPTs, accurate numerical models for the detailed design are still in progress. Each of the three phenomena need to be simulated with a dedicated strategy, to prevent the excessive computational burden associated to multi-scale mechanisms.

This work presents a numerical suite targeted at MEPTs that has been developed in the frame of a collaboration between the University of Padova, T4i, and the University of Bologna. The EM problem is solved by means of the well-established 3D solver ADAMANT. The plasma production in the source is handled with the 3D-VIRTUS code that relies on a fluid model. The plasma expansion in the magnetic nozzle is simulated with a fully kinetic Particle-In-Cell approach; both a 3D and a 2D solver (SPIS and

Starfish respectively) are available. The mutual interactions between solvers will be discussed, and a comparison between different methods as well as benchmarking of the results against experiments will be presented. Thus the reliability of the numerical suite will be evaluated for the first time. This powerful tool will aid the optimisation of MEPTs and, in turn, will contribute to increasing their widespread application on space missions, in particular on the CubeSat segment.