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MULTI-OBJECTIVE DESIGN OPTIMIZATION OF THE CUSPED FIELD THRUSTER FOR MICRO-SATELLITE PLATFORMS

Abstract

For in-situ propulsion systems, electric propulsion (EP) offers significant advantages over chemical propulsion. EP systems deliver up to an order of magnitude better fuel efficiencies than their chemical counterparts, which subsequently reduces payload mass and therefore launch costs. The High-Efficiency Plasma Thruster (HEMP-T) [1] or Cusped Field Thruster (CFT) [2] is a new concept in the field of electric propulsion that employs a permanent periodic magnet arrangement inspired by traveling wave tube technology to confine and accelerate plasma. Efforts have been made to characterize the performance of the thruster and to downscale the design into micro-newton thrust resolutions, however, this has been coupled with significant losses in performance [3]. Building on previous work [4], which utilized a one-dimensional power distribution analysis based upon the magnetic topology developed by a group at Thales Electron devices, it was found that the magnetic topology and the anode current played significant roles in the thruster's performance. We aim to provide a more thorough analysis and further validate the results of our optimization and present an optimal design for the micro-satellite class platform. This study applies an advanced design methodology combining state of the art multi-physics software and evolutionary algorithms assisted by surrogate modeling to a multi-objective optimization for the performance optimization and characterization of the CFT. The multi-physics software provides a multi-dimensional analysis of the thruster physics, providing data on the magnetic topology, plasma interactions, and the electrical properties which will inform the evaluation algorithm that evaluates each design iteration per a set criteria and extrapolated performance metrics. Optimization is performed to maximize the performance defined by key parameters, simultaneously aiming to maximize 3 primary objectives, that is, thrust, efficiency and specific impulse. The optimization results are assessed via global sensitivity analysis in conjunction with surrogate models to identify critical design factors regarding the primary objectives and additional performance measures.

[1] Kornfeld, et al., Physics and evolution of HEMP-thrusters. In Proceedings of the 30th International Electric Propulsion Conference, 2007, pp. 17-20).

[2] Courtney DG, Lozano P, Martinez-Sanchez M. “Continued investigation of diverging cusped field thruster”. AIAA Paper. 2008 Jul; 4631:2008.

[3] Keller, A., ”Feasibility of a down-scaled HEMP Thruster”, Phd, Justus-Liebig-University Gießen, 2014.

[4] Muffatti, A. and Ogawa, H., “Multi-Objective Design Optimisation of a Small Scale Cusped Field Thruster for Micro Satellite Platforms”,Inproceedings of:16thAustralian Space Research Conference, Melbourne, Australia, Sep 2016