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EXPERIMENTAL VALIDATION OF THE USE OF ADDITIVE MANUFACTURING AND METAHEURISTIC INVERSE DESIGN TO DEVELOP AN ELECTRODELESS PLASMA THRUSTER

Abstract

Electric propulsion systems have become commonplace as satellite subsystems, so there is an increased appetite for methods that improve the lifetime, weight, and efficiency of existing technologies. Vast improvements in additive manufacturing and computing power are creating opportunities for improved optimisation of the magnetic circuits that directly impact electric propulsion system performance. The combination of magnetic circuits and plasma presents an inverse design problem, requiring the use of sophisticated metaheuristic or machine learning techniques to produce effective solutions. The presented novel evolution-based optimisation strategy relies on an objective function that assesses candidate solutions based on a simplified numerical model for plasma behaviour within a magnetic nozzle. This model includes an axisymmetric magnetostatic simulation of the effect of different magnet locations on the resulting B-field. Objective function effectiveness was evaluated with VSim particle-in-cell (PIC) simulations of a series of candidates, using PIC models validated in an earlier study. It was found that there is a trade-off between magnetic mirroring, peak field strength, and inferred plume divergence for achieving maximum thrust performance. The best scoring candidate was configured using an array of Neodymium magnets, confined at the required locations within a 3D printed PVDF (Kynar) vessel, with the array situated around a RF Argon plasma source (half-helix Helicon antenna). For comparison, a lower scoring device was also constructed using the same core plasma source. Langmuir probe and retarding potential analyser results showed an increase in ion flux, density, and a 10% increase in ion energy for the best scoring candidate at 100W power, as well as an agreement with particle-in-cell simulation results. The successful use of this technique supports efforts to apply the inverse design of magnetic circuits to other devices such as hall effect thrusters.