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APPLICATION OF PARTICLE-IN-CELL SIMULATION TECHNIQUES IN THE ANALYSIS AND OPTIMISATION OF MAGNETIC NOZZLE GEOMETRIES

Abstract

Modern electrical propulsion techniques are becoming increasingly practical for long range, high ΔV space missions. For this trend to continue, the overall efficiency of electric thrusters needs to be continually improved. As magnetic nozzles have an influence on their overall thrust efficiency, greater innovation in their design could facilitate this objective. Today, powerful computational tools are readily available to ensure that a wide range of new designs are fully investigated before being prototyped. Due to the high velocities and complex interactions between ions within these thrusters, Particle in Cell algorithms are currently considered to be far more accurate than fluid-dynamic methods in simulating their behaviour. However, the trade-off is computational cost, as the algorithms solve Maxwell's and Poisson's Equations for individual groups of particles.

This paper demonstrates the use of a two-dimensional, relativistic Particle in Cell algorithm for accurately simulating the acceleration of plasma ions through a magnetic nozzle. Achieved using the multi-physics software tool V-Sim, provided by the Tech-X corporation. In particular, we show that these simulations are very effective at determining whether plasma detachment occurs, which is a critical element of magnetic nozzle design. The effect that this technique has on the optimisation of magnetic nozzle designs that are suitable for small to large scale plasma-dynamic thrusters is also discussed. The thrusters analysed include the Cubsat Ambipolar thruster and the VASMIR rocket. These simulated designs, verified against theoretical calculations, also offer significant insight into the physics behind the thrusters operation.