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MAGNETOHYDRODYNAMIC SIMULATION OF MAGNETIC NOZZLE OF VASIMR® CONCEPT

Abstract

Radio frequency (RF) plasma engine is a type of plasma propulsion device which has several advantages over other electric propulsion systems, such as the ability to generate variable specific impulse and thrust, and reduced wear. It primarily consists of three sections: i) helicon plasma generator, ii) ion cyclotron resonance heater (ICRH), and iii) magnetic nozzle. The helicon plasma generator excites the propellant gas by RF waves and converts it into cold plasma. The cold plasma is then energized in ICRH by excitation with different RF waves and gets transformed into hot energized plasma. Finally, this energized plasma is expanded through the magnetic nozzle, where a diverging magnetic field exists. Here, the cyclotron motion of particles in the energized plasma gets converted to axial motion producing thrust. The prime objective of this study is to simulate plasma behavior in a magnetic nozzle of RF engine and to examine the effect of variation of several design parameters on thrust generation. In this study, plasma is simulated using magnetohydrodynamics approach, where plasma is modeled as a continuum, in which continuity, momentum and energy equations are solved along with Maxwell's equations. USim, software developed by TechX Corporation, is used to carry out the simulations on a 2-D planar geometry. The approach is validated with experimental data from the literature. Further, a parametric study is carried out to investigate the influence of applied magnetic field strength and plasma inlet number density in the magnetic nozzle, on both thrust generation and plume detachment positions. Results show that thrust increases as the applied magnetic field strength or plasma inlet number density is increased. This is due to the fact that the Lorentz force in the magnetic nozzle, which is responsible for thrust generation, depends on the gradient of magnetic field strength in the axial direction; hence an increase in magnetic field strength results in augmentation of thrust. The increase in thrust due to increase in plasma number density can be attributed to the increase in plasma flow rate through the nozzle. Additionally, the study of plume detachment position revealed that the plume detaches approximately where the particles attain

velocities greater than the Alfvenic velocity. However, the parameters considered do not have a significant effect on the location of plume detachment.