INTEGRITY OF THE PLASMA MAGNETIC NOZZLE

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The injection of hot (100s of eV) plasma propellant into a nozzle composed of shaped magnetic flux to convert the plasma thermal energy into directed thrust is fundamental to enabling high-specific impulse (10 000s of seconds) and high-specific power (10s of kW/kg) piloted interplanetary propulsion. This report pertains to the theoretical physics governing certain aspects of the flow of plasma propellant through a magnetic nozzle, primarily the integrity of the interface between the plasma and the nozzle's magnetic field, for these operational parameters. An expression for the initial thickness of the interface is derived and found to be significant (on the order of 10–2 m). A comparison is made between classical resistivity and gradient driven Lower Hybrid Drift microturbulent (anomalous) resistivity, from which an algorithm is derived that obtains interface thickening as a time integral, that is then related to the nozzle-shaped geometry of the interface. An algorithm characterizing the plasma temperature, density, and velocity dependencies is derived and found to be comparable to classical resistivity at local plasma temperatures on the order of 200 eV. Macroscopic flute mode instabilities within the interface in regions of adverse magnetic curvature are discussed and a practical growth rate formula for magnetic nozzle design is derived. It is calculated that only one to two e-foldings of the most unstable Rayleigh-Taylor mode would occur. For a more complete treatment of the Rayleigh-Taylor effect it will be necessary to include the Hall effect as well as ion magnetoviscosity. The necessity of incorporating the Hall effect into Ohm's law is discussed, where the full Hall current is able to flow and concomitant plasma rotation allowed. In that case, a critical nozzle length expression is derived below which the interface thickness is limited to about one ion gyroradius.