Fluid Simulation of Plasma Flow in a Magnetic Nozzle*

Alfonso G. Tarditi

Advanced Space Propulsion Laboratory, NASA Johnson Space Center, Houston, TX (USA)

A magnetic nozzle configuration is determined when a magnetically confined plasma is flowing along diverging field lines. This configuration is particularly relevant for electric propulsion devices that use a plasma as propellant [1-3].

The design of a magnetic nozzle is a critical issue for plasma propulsion as it affects thrust and efficiency. In a properly designed device, the plasma flow modifies and eventually detaches from the magnetic field of the nozzle (carrying some magnetic field with it, similarly to what is observed in the Sun).

The magnetic nozzle topology arises also naturally in the open-field line region of a field reversed configuration (FRC). In FRC and plasma thruster experiments a conducting end plate is typically present (at least on the opposite side of the nozzle), producing shorting of the magnetic field lines and an azimuthal rotation that may affect the flow in the nozzle [4]

To address these issues, a fluid simulation model has been implemented with the *NIMROD* code [5]. The simulations reproduce detachment conditions where a transition from sub- to super-Alfvenic flow occurs. The similarities with a converging-diverging gas-dynamic de Laval nozzle, in which the acceleration from subsonic to supersonic flow is characterized by a transonic “choking” condition at the nozzle throat [6], are discussed.

Simulation runs of the plasma flow pattern in different regimes for a basic de Laval-type magnetic nozzle are presented both for the MHD and for the two-fluid formulation.

REFERENCES

[1] F. R. Chang-Diaz, Scientific American, p. 90, Nov. 2000
[2] E. Y. Choueiri and J. K. Ziemer, Jour. Propulsion and Power, 17 (5), p. 967, 2001
[3] F.R. Chang Díaz, 39th AIAA/ASME/SAE/ASEE, Joint Propulsion Conference Huntsville, Alabama, AIAA 2003-4997, 2003
[4] L. C. Steinhauer, Phys. Plasmas, 9 (9), p. 3851 (2002)
[5] http://www.nimrodteam.org
[6] M. C. Goossens, An Introduction to Plasma Astrophysics and Magnetohydrodynamics, Kluwer Academic, Dordrecht, The Netherlands, 2003

* *Work supported by NASA*