Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: PROPHY / STUDENT *(3 maximum from the list of topics)*
Corresponding author: TKACHENKO Yevhen
e-mail of corresponding author: yevhen.tkachenko@obspm.fr
Type: Oral
Status of corresponding author: Student
For student corresponding author: student member of one of the following:
3AF / AAAR / AIAE / AIDAA / CzAeS / DGLR / FTF / NVvL / PSAA / RAeS / SVFW / EUROAVIA

Title

Resistive MHD simulations of a self-field Magneto Plasma Dynamic thruster over the 5 to 40 kA current range

Authors

Yevhen TKACHENKO[1], Andrea CIARDI[1], Benjamin KHIAR[2]*

** Corresponding author*
[1] Sorbonne Université, Observatoire de Paris, PSL Research University, LERMA, CNRS UMR 8112, 75005 Paris, France, yevhen.tkachenko@obspm.fr, andrea.ciardi@obspm.fr
[2] Office National d'Etudes et de Recherches Aérospatiales (ONERA) Palaiseau 91123, France, benjamin.khiar@onera.fr

Abstract

Magnetoplasmadynamic thrusters (MPDTs) are promising devices in the electric space propulsion family where acceleration is done by the Lorentz force. It has been shown analytically that the thrust produced by MPDT is dependent on the square of the driving current [1, 2]. Such behavior has been confirmed by experiments for relatively low current levels, but it was seen to fail at higher currents, where the so-called "onset" occurs [3]. Despite many theoretical and experimental studies, summarized in [4], the cause of this breakdown remains unclear. Numerical simulations of self-field MPDTs have investigated subcritical or near-critical current regimes [5], the role of thermal phenomena [6] and of an applied magnetic field [7].

The aim of the present numerical work is to investigate the physics of self-field MPDTs over a range of currents including the high current regime where the onset is thought to occur for the simulated setup. We run single-fluid, two temperature, resistive magneto-hydrodynamic (MHD) simulations in 2D cylindrical axisymmetric geometry using the parallel, finite-volume code FLASH. The simulations also include thermal conduction and Braginskii transport coefficients are used.

Here we present results for currents spanning the range 5 kA to 40 kA. The simulations recover the two expected operational regimes, which are characterized by the dominant mechanism that is responsible for the acceleration of the plasma: the pressure gradients at low currents and the Lorentz force at intermediate currents. Comparison of the simulations results with existing theoretical and semi-empirical models [8] shows good agreement. We find that the simulated plasma remains stable at high current levels (>20 kA) and does not exhibit the unstable behavior of self-field MPDTs observed in experiments for such strong currents.

In conclusion, while the simulations can reproduce the correct dependence of the thrust on current, the geometry and physics considered in the model are unable to capture the onset. Future work will explore the importance of 3D effects as well as extended MHD physics on the ability of the model to capture the onset. Extension to 3D is of great importance in particular to capture non-axisymmetric MHD instabilities.

References

[1] Maecker, H., Zeitschrift für Physik, 141.1, 1955, pp. 198–216.
[2] Jahn, R. G. and Lyman, F., 1968.
[3] Boyle, M.; Clark, K., and Jahn, R., AIAA Journal 14.7, 1976, pp. 955–962.
[4] Andrenucci, M., Encyclopedia of Aerospace Engineering, 2010.
[5] Sankaran, K.; Choueiri, E., and Jardin, S., Journal of propulsion and power 21.1, 2005, pp. 129–138.
[6] Kawasaki, A. et al., 51st AIAA/SAE/ASEE Joint Propulsion Conference, 2015, p. 3727.
[7] Chelem Mayigué, C.; Kühn, C., and Groll, R., Journal of Applied Physics 124.22, 2018, p. 223301.
[8] Choueiri, E., Journal of Propulsion and Power 14.5, 1998, pp. 744–753.