# MagJet

## 3D Simulation of a magnetoplasmadynamic thruster with coaxial induced magnetic field

***Charles Chelem Mayigué, M. Sc., PD Dr.-Ing. Rodion Groll***, *ZARM - Center of Applied Space Technology and Microgravity*

### In Short

- Magnetohydrodynamic
- Magnetoplasmadynamic
- Compressible flow
- Lorentz force
- Magnetic pressure
- ...

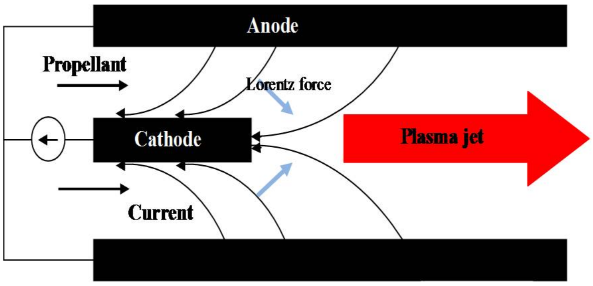


***Figure 1:*** *Schematic view of a self-field MPD Thruster*

Despite the advances in combustion research, the highest exhaust velocity of a functional chemical propulsion system, 3.600 to 4.500 m/s from sea level to high altitude, is still inadequate for most deep-space missions of interest. The present situation of space exploration calls for missions beyond the moon and for such missions, chemical propulsion is not a viable option, except for the case of launch vehicles where high thrust is required. Functionally, the inability of chemical propulsion systems to achieve higher exhaust velocities is due to limitation in the maximum tolerable temperature in the combustion chamber and to avoid excessive heat transfer to the walls. Both these limitations can be overcome by use of electric propulsion, which can be defined as the acceleration of gases for propulsion by electrical heating and/or by electric and magnetic volume forces. The magnetoplasmadynamic (MPD) thrusters have the unique capability, among all other developed electric propulsion systems, of processing megawatt power levels in a simple, small and robust device, producing thrust densities as high as $10^5\ N/\ m^2$. These features render it an attractive option for high energy deep space missions requiring higher thrust levels than other electric thrusters. In its basic form, the MPD thruster consists of a cylindrical cathode surrounded by a concentric anode (Figure 1). An electric arc between the electrodes ionizes a gaseous propellant, and the interaction of the current with the self-induced magnetic field accelerates the plasma to produce thrust. The specific impulse of a self-field MPD thruster is related to the parameter $\frac{I^2}{\dot{m}}$ which is often used to characterize MPD thruster performance. High value of $\frac{I^2}{\dot{m}}$ correspond to predominantly electromagnetic acceleration, and provide higher values of specific impulse. Low values of $\frac{I^2}{\dot{m}}$ correspond to predominantly electrothermal acceleration, and lower values of specific impulse. MPD efficiency typically increases with increasing $\frac{I^2}{\dot{m}}$, but this also leads to strong numerical instabilities [1], which makes the solvers unstable and undermines its value. For modeling of the thruster, CFD code is required to understand the complex nature of the coupled electromagnetic and gasdynamic acceleration processes and the effects of relevant flow-field parameters which are otherwise quite hard to analyse with experiments. With the emergence of high-speed computational facilities, CFD code permits model validation using the existing experimental data base.

In the present work, we describe the implementation of a density-pressure-based method for the simulation of the magnetohydrodynamic (MHD) equations under a finite volume formulation. This new algorithm was developed for the single resistive MHD equations and make use of the central-upwind scheme of Kurganov and Tadmor for flux calculation. Electrical conductivity is predicted according to the Spitzer-Härm formulation.

The ultimate goals of the MagJet project are:

1. To develop a strong computational model in which the governing equations of relevant physical processes are solved using a reliable numerical scheme. For this purpose some simulations are necessary to identify the optimum boundary conditions, to make a geometric scaling and to study their impact on our MPD performance and efficiency.
2. Use the results of these simulations to obtain insight into the physics of thrust production and energy dissipation in these devices.
3. Use this code to understand the operating conditions of a specific type of thruster for which experimental data are not available or not accurate.

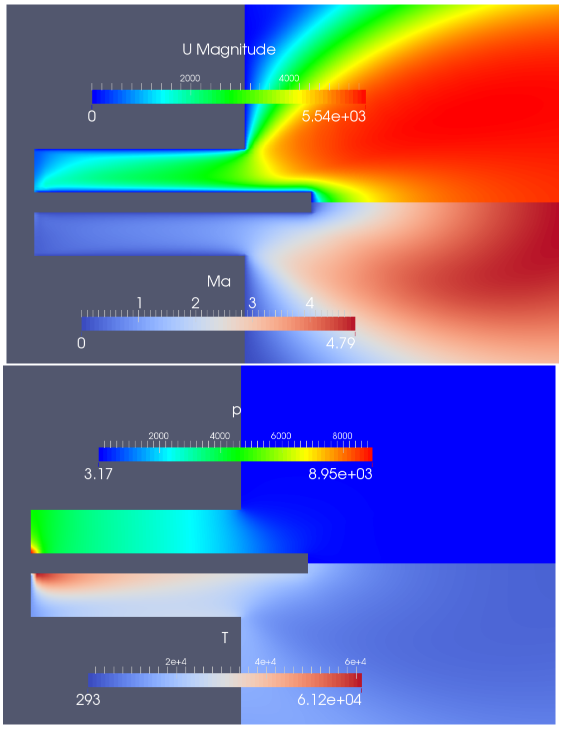
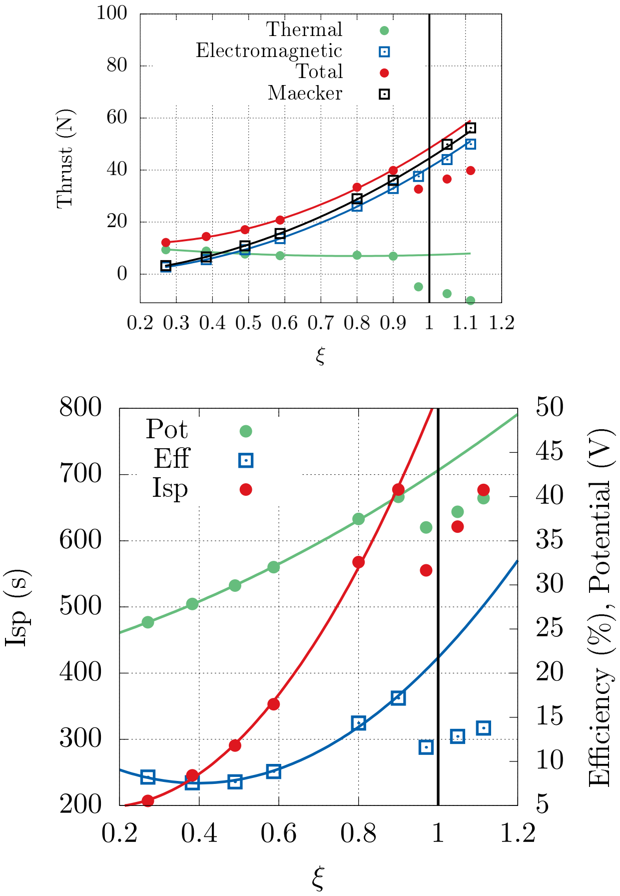


***Figure 2:*** *Velocity magnitude and Mach number (top); Pressure and Temperature (bottom) after 12 ms with* $\frac{l_a}{r_a} = 4$ *and* $I = 8290\ A$*. The mass flow rate of argon and the temperature at inlet are* $6.0 \times 10^{-3}\frac{Kg}{s}$ *and* $T_{inlet} = 1\ ev$ *respectively*



(...)

***Figure 3:*** *Steady state thrust (a) and Calculated specific impulse, voltage and efficiency (b) for the MPDT01 thruster with* $l_c = 0.132\ m$, $\frac{l_a}{r_a} = 04$, $\dot{m} = 6\ g/s$

(. . . )

## WWW

https://www.zarm.uni-bremen.de/

## More Information

[1] https://www.zarm.uni-bremen.de/research/space-science/thermofluid-dynamics/projects/mhdjet.html#c5869

[2] https://www.zarm.uni-bremen.de/research/space-science/thermofluid-dynamics/tools/zarm-rho-central-mhd-foam.html#c6704

## Funding

DAAD