# FINITE VOLUME SIMULATION OF 2-D AND 3-D NON-STATIONARY MAGNETOGASDYNAMIC FLOW

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***Abstract* — This work presents the development of the ideal and real magnetogasdynamic (MGD) equations in two and three spatial dimensions, followed by a modern numerical resolution method. The equations that govern the MGD flows are continuity, momentum, energy and magnetic induction together with a state equation. The method of Roe has been applied, in a high resolution Total Variation Diminishing scheme, with modifications proposed by Yee et al. For the implementation of this method in finite volumes a FORTRAN code has been developed, and it has been applied to the resolution of the magnetogasdynamic Riemann problem and the Hartman flow. Due to the high computational cost demanded by a 3D simulation, it has been necessary to reduce the grid density, compared to that used on the unidimensional and bidimensional cases. In order to evaluate this last issue, an analysis of the effect of the grid density on the results has been included at the end of the present work. The magnetogasdynamic shock tube and the Hartman flow, used as "benchmarks", have been satisfactorily solved.**

***Keywords* – Magnetogasdynamics, Riemann problem, Hartman flow, TVD scheme.**

## I. INTRODUCTION

The magnetogasdynamics is the branch of physics that studies the flow of compressible ionized fluids. The governing equations are those of continuity, Newton´s second law, conservation of energy, Maxwell´s equations and equations of state for the involved fluids. This set of equations must be completed, with thermochemical models for fluids at very high temperatures (D´Ambrosio and Giordano, 2004). The magnetogasdynamic analysis can be classified in three categories, depending on the hypothesis assumed for the flow and the governing equations:

-Ideal Magnetogasdynamics (IMGD): the system is described by Euler equations plus the magnetic induction equation.

-Real Magnetogasdynamics (RMGD): the system is described by Navier-Stokes equations plus the magnetic induction equation

-Complete Magnetogasdynamics (CMGD): the system is defined by the coupled Navier-Stokes and Maxwell equations.

In all cases it is possible to have more than one specie and chemical reaction between them, which are modeled as source terms. It is also necessary to specify equations of state.

The main objective of this work is to present the results obtained with a computational code developed to solve the non-stationary 3-D ideal and 2-D real magnetogasdynamic equations using an approximated Riemann solver and with a Total Variation Diminishing (TVD) scheme. This research intends to contribute to achieving a comprehensive description of the ablative pulse plasma thruster (APPT) behavior. There is previous work (Elaskar and Brito, 2001) in which the authors use numerical codes to simulate the flow inside of magnetoplasmadynamics thruster.

The new 3-D code presented in this work is a natural extension of the 2-D code developed by Maglione (2004) and the works of Maglione *et al.* (2003, 2007).

An application of particular interest of IMGD is the propagation of waves in solar magnetic loops (Fernandez *et al.*, 2009) and the evolution of solar tadpoles (Costa *et al.*, 2009).

Among other researchers work in this line, Keppens (2001) uses Roe´s approximation to a Riemann solver, Sankaran (2003) develops a "Local Extremum Diminishing-LED" scheme, D´Ambrosio *et al.* (2004) solve the time-dependent complete magnetogasdynamics equations (CMGD) in one spatial dimension and Loverich (2004) simulates the Magnetohydrodynamic (MHD) equations considering two substances, with Roe´s approximation.

This work offers a comparison between the results obtained with our 3-D ideal MGD code and those obtained with the previous 2-D code, in order to validate the first one. During the tests of our software, which were performed using a lower density mesh, due to our limited computing facilities, slight differences were noticed between the results and those obtained with a higher density mesh in 2-D. For that reason it was decided to extend the scope of this work, by carrying out a comparison between the results obtained with meshes of different density. In this way it was possible to establish the effect that the mesh density introduces in the results in this sort of problems and to confirm that the differ-