MHD SUPERSONIC FLOW CONTROL SIMULATION IN OPENFOAM

ALEXEY RYAKHOVSKIY[1], ALEXANDER SCHMIDT[2]
[1]Ioffe Institute, Saint-Petersburg, Russian Federation, alexey.i.ryakhovskiy@mail.ioffe.ru
[2]Ioffe Institute, Saint-Petersburg, Russian Federation, alexander.schmidt@mail.ioffe.ru

Keywords: *magnetohydrodynamic and fluid equation, finite volume methods, supersonic flows, ionized gas flow in electromagnetic fields, flow control*

Atmospheric descent presents a number of obstacles for an entering spacecraft by both drag and heating, which can result in damage or even destruction. One of the methods for solving these problems is magnetohydrodynamic (MHD) flow control. It is based on the concept of affecting the compressed and ionized gas in front of the spacecraft with the magnetic field. This interaction allows for drag control and heat flux reduction by pushing away hot ionized gas.
We aim to develop a numerical model and a set of OpenFOAM solvers capable of solving the problem of MHD supersonic flow around bodies of different shape. We benefit from the fact that there is already a number of stable supersonic solvers both in standard OpenFOAM set as well as in its extensions.
Two different solvers for MHD supersonic flow have been developed. First one is based on central difference schemes for MHD equation, proposed by Balbas and Tadmor [1]. Second one is a Godunov-type method with Roe linearization, utilizing Harten-Lax-vanLeer Riemann solver [2]. Both are modifications and extensions of the existing solvers: *rhoCentralFoam* and *dbnsTurbFoam* respectively. MHD terms were added to them accordingly.
The performances of developed solvers have been compared on a number of test cases including flows with Mach number ranging from 2 to 4.5 and Stuart number - from 0 to 0.3. Geometry of the test cases uses the shapes of existing descent spacecrafts. The computational domains are 5 degree wedges of axially symmetrical geometries. Both solvers are relatively stable for Stuart numbers below 0.2, while when higher local Stuart number is reached, instabilities tend to occur. Godunov-type solver is predictably better at resolving sharp shock front. It has been shown that even relatively small (St = 0.2) magnetic field can have a considerable effect on shock wave configuration. Theoretical estimates of heat flux reduction and shock standoff distance increase were confirmed. Numerical results were shown to agree with experimental data by comparison of numerical density fields to interferograms and shadowgraphs of experimental flows. Further development should include improving solvers' stability as well enhancing mathematical model of phenomenon.

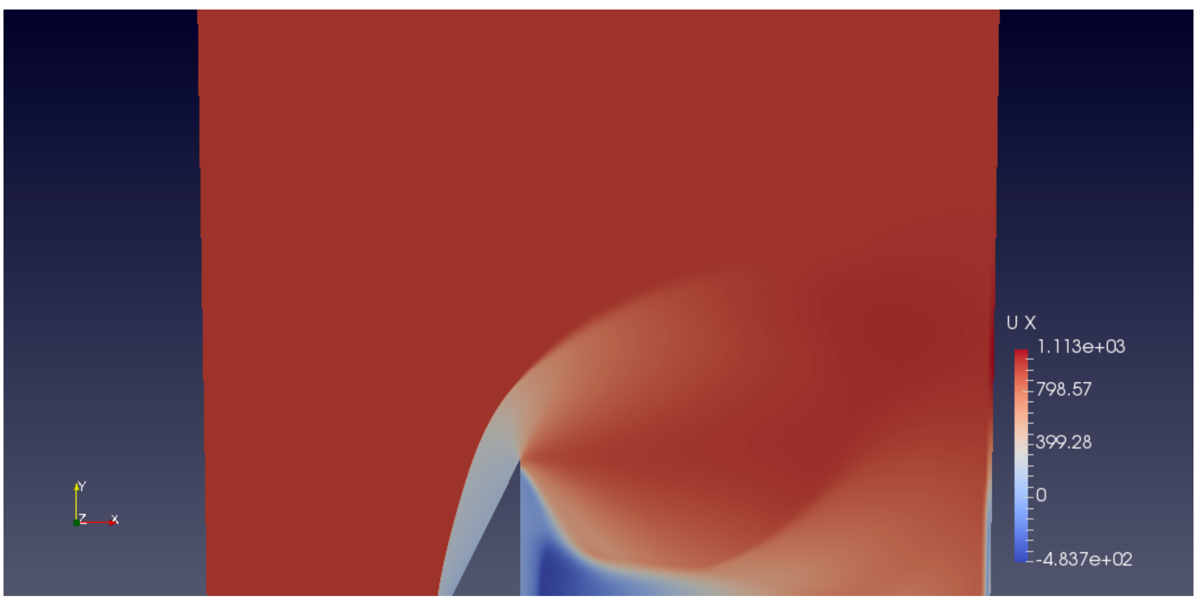

Figure 1: Typical bow shock shape with longitudinal velocity field (Mach=3).

References

[1] J. Balbás, E. Tadmor, "Nonoscillatory central schemes for one-and two-dimensional magnetohydrodynamics equations", *SIAM J. on Scientific Computing*, vol. 28, no. 2, pp. 533-560, 2006.

[2] P. Janhunen, "A positive conservative method for magnetohydrodynamics based on HLL and Roe methods", *J. of Computational Physics*, vol. 160, no. 2, pp. 649-661.