Numerical Simulation of Magnetohydrodynamics Flow in Wavy Wall Channel using Immersed Boundary Method

Prerit Sharma and Ranjith Maniyeri*

Biophysics Laboratory, Department of Mechanical Engineering,
National Institute of Technology Karnataka (NITK), Surathkal 575025, Karnataka, India
* Corresponding author E-mail address: mranji1@nitk.edu.in (R. Maniyeri)

1. INTRODUCTION & OBJECTIVE

Magnetohydrodynamic (MHD) flow in a channel has significant potential for industrial applications, including plasma physics, metallurgy, nuclear engineering, and fusion reactors. Also, it has applications in medical sciences such as peristaltic flow, pulsatile flow, and drug delivery. MHD is a branch of physics that studies the behavior of a fluid that is electrically conducting under the influence of magnetic fields.

The present study is an attempt to apply the IB methodology for the computation of both the hydrodynamic and MHD fields. Initially, a numerical simulation of the plane Poiseuille flow with a magnetic field is carried out. Then, a numerical investigation of MHD fluid flow is carried out for two wavy-walled channel (plane Poiseuille flow) configuration. A two-dimensional computational model based on an immersed boundary finite volume method is developed to perform numerical simulation on a staggered Cartesian grid system. Further, the pressure-velocity coupling governing continuity and the Navier-Stokes equations describing the fluid flow are solved. A forcing term is added to the Navier-Stokes equation in order to impose the magnetic field effect on the flow of the conducting fluid. Fluid variables are described by Eulerian coordinates and solid boundaries by Lagrangian coordinates. The linking of these coordinate variables is done using the Dirac delta function.

Keywords: Magnetohydrodynamics, Immersed boundary method, Dirac delta function, Fluid-structure interaction.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Initially, a numerical simulation of the plane Poiseuille flow with a magnetic field is carried out, and the effect of MHD phenomena is studied using a velocity and pressure contour plot. With respect to figures 1 and 2, it can be seen that the magnetic effect (Hartmann number, Ha) opposes the flow, which reduces the maximum velocity of fluid flow. Then, a numerical simulation of the Poiseuille flow with two wavy virtual walls in fluid flow was carried out. With respect to figure 3, it can be seen that flow velocity increases in the throat section, and downstream of the throat, recirculation starts to occur due to an adverse pressure gradient. Then, a numerical simulation of the MHD flow with two wavy virtual walls was carried out. With respect to figure 4, it can be seen that increasing the Ha number reduces the flow velocity in throat sections and reduces the effect of vortices downstream of the throat in the wavy walls.

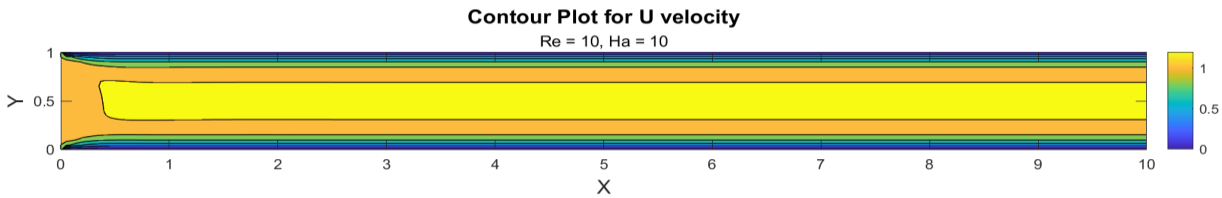

Figure 1. Contour plot of U velocity for a Plane Poiseuille MHD flow with Ha = 10.

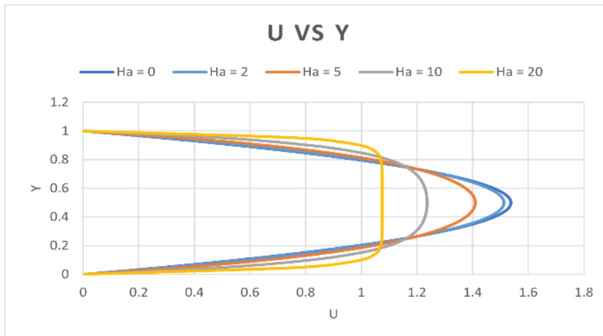

Figure 2. U velocity for a Plane Poiseuille MHD flow varying in the y-direction for different Ha values.

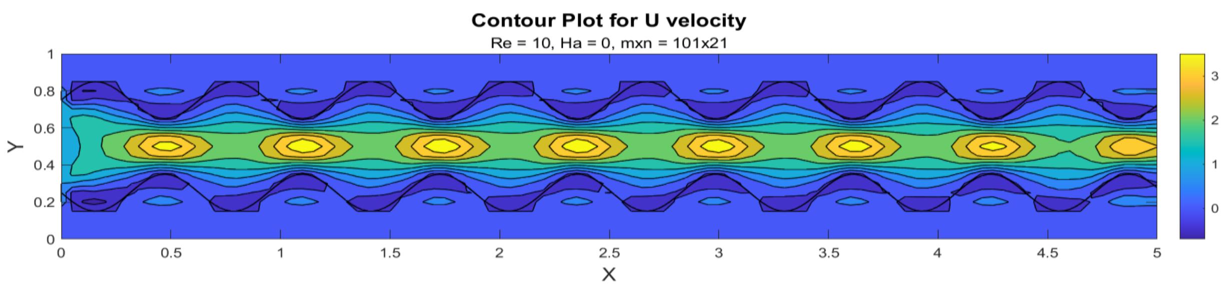

Figure 3. Contour plot of U velocity for Plane Poiseuille flow having 2 wavy virtual walls without magnetic effect.

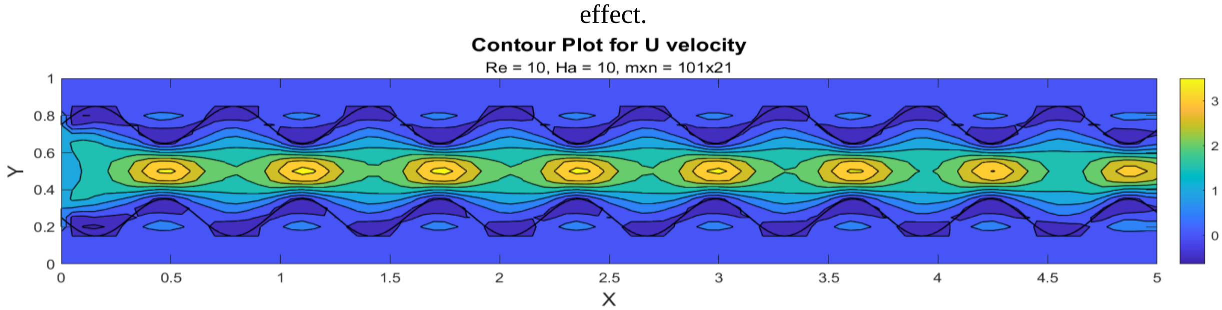

Figure 4. Contour plot of U velocity for Plane Poiseuille MHD flow having 2 wavy virtual walls with magnetic effect (Ha = 10).

REFERENCES

1. L. Bühler, H. J. Brinkmann, C. Koehly, "Experimental study of liquid metal magnetohydrodynamic flows near gaps between flow channel inserts", *Fusion Engineering and Design*, **146**, pp. 1399-1402, 2019.
2. Sergen Tumse, Besir Sahin, "Influence of uniform magnetic field on hydrothermal characteristics and entropy production in a nanofluid filled rectangular grooved channel", *Case Studies in Thermal Engineering*, **45**, 102973, ISSN 2214-157X, 2023.
3. He Wang, "Mixed convection in volumetrically heated magnetohydrodynamic flows around a 180-degree sharp bend", *International Journal of Heat and Mass Transfer*, **208**, 123844, ISSN 0017-9310, 2023.
4. Jiatao Guo, Yongchang Chen, Jincao Hu, Ziyan Xu, Chongfang Ma, "Numerical study on the flow and heat transfer of molten salt in a horizontal pipe applied transverse magnetic field", *International Journal of Thermal Sciences*, **192**, Part B, 108416, ISSN 1290-0729, 2023.