Studying Magnetohydrodynamic Effects in Liquid Metal Flow Under Transverse Magnetic Field Using COMSOL Multiphysics®

S Sahu[1], R. Bhattacharyay[1], E. Rajendrakumar[1]

[1]Institute for Plasma Research, Bhat, Gandhinagar, India

Abstract

Liquid metals, having higher heat capacity, are foreseen as a multipurpose coolant in fusion blanket systems. The liquid metal is circulated in a closed loop within the blanket system to extract the high-grade nuclear heat, generated inside the fusion reaction. However, the strongly magnetic environment of the fusion reactor hinders the regular flow of the liquid metal. The electrically conducting liquid metal interacts with transverse magnetic field and produces a Lorentz force opposing the liquid metal flow. As a result, the regular flow profile in the circular pipe or rectangular ducts gets modified. The modified flow profile has an adverse effect on heat transfer and pressure drop in the blanket system. Hence, it is necessary to study the liquid metal fluid flow dynamics under strong transverse magnetic field. Complex geometry and lack of sophisticated diagnostics at high temperature and magnetic field environment make it impractical to measure all the process parameters accurately. As an alternative approach, validated numerical tools may be used for predicting the process design parameters. Recently, COMSOL Multiphysics® has been used as a numerical tool for simulating the magnetohydrodynamic flow of Pb-Li in a pipe under various Hartmann numbers. The simulation results are compared with that of well-known Hunt's analytical relations. In this paper, the comparison of numerical and analytical results has been shown to infer the applicability of COMSOL in studying LM MHD phenomenon.

Some preliminary results on MHD analysis using COMSOL (Not Included in the abstract):
In the figure attached, preliminary COMSOL analysis results for a rectangular straight channel flow under transverse magnetic field are compared with available analytical results, obtained by Dr. J.C. Hunt. It is to be noted that the "side walls" are those walls of the rectangular channel, for which the magnetic field is parallel to the wall. The walls for which the magnetic field is perpendicular are called Hartmann wall. This paper will basically demonstrate the successful benchmarking of COMSOL.

Reference

1. J.C.R. Hunt, “Magnetohydrodynamic flow in rectrangular ducts”, J. Fluid Mech. (1965), vol. 21, part 4. Pp. 577-590
2. “Magnetofluiddynamics in Channel and containers” , U. Muller, L. Buhler, Springer.
3. “Magnetohydrodynamics”, R. MOREAU, Vol3, kluwer academic publishers.

Figures used in the abstract

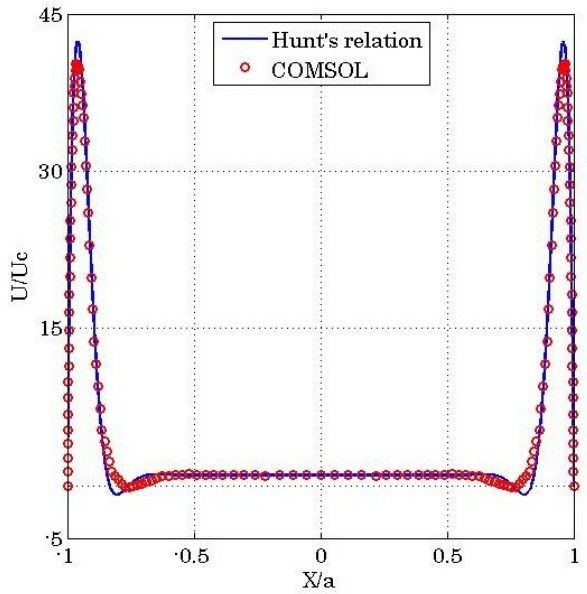

Figure 1: Comparison of Non-dimensional velocity across the side wall. Formation of velocity jet near the side wall boundary layer could be nicely captured.

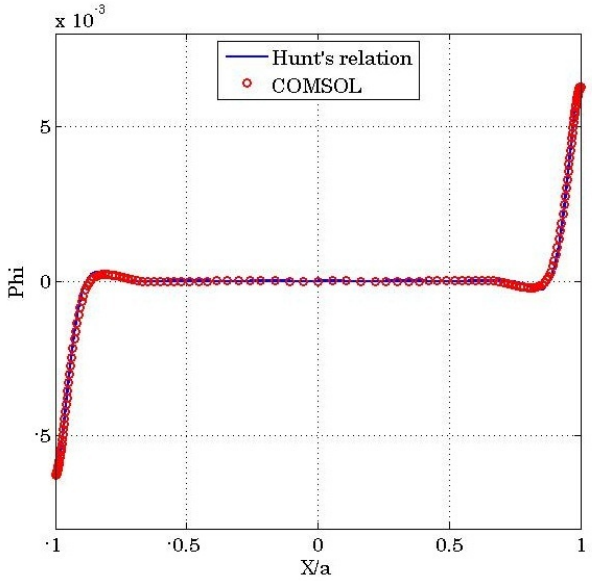

Figure 2: Comparison of Non-dimensional electric potential across the side walls