THE DEVELOPMENT OF 3D MHD CODE IN COMSOL MULTIPHYSICS AND ITS APPLICATION FOR MHD FLOW IN RIPPLED MAGNETIC FIELD

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1. INTRODUCTION

In fusion liquid metal blankets, liquid metal motion under plasma-confining magnetic fields induces magnetohydrodynamic (MHD) effects, generating characteristic velocity profiles and significant pressure drops. A 3D MHD numerical code was developed using COMSOL Multiphysics with the magnetic induction equation. Validation against benchmark cases (Shercliff/Hunt analytical solutions, non-uniform magnetic field experiments) and comparison with verified codes confirms its reliability. The code reveals how magnetic field gradients influence MHD pressure drops and boundary jet formation. The fusion reactor confinement fields feature radial gradients and inter-coil magnetic ripples. Tritium breeding blanket pipes traversing these gaps experience complex MHD interactions. Using the validated code, systematic studies of rectangular and circular pipe MHD under rippled fields provide critical insights for optimizing blanket performance.

Table I. Dimensionless parameters of Narendra Gajbhiya validation results.

Case number	Case 1	Case 2
Hartmann number, ***Ha***	50	100
Wall conduction ratio, C_w	0.1	0.1
Interaction Number, ***N***	1×10^3	1×10^3

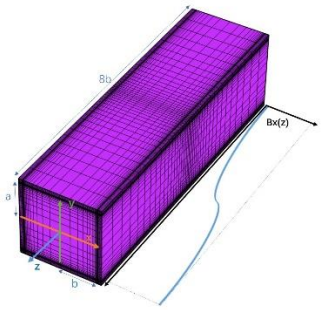

Fig. 1. Schematic of rectangular pipe with imposed non-uniform background magnetic field in x direction.

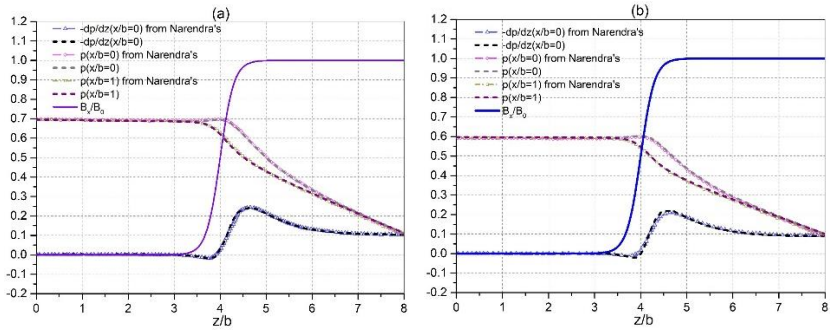

Fig. 2. Comparison of the profiles of the axial(z=0) pressure and pressure gradient in the longitudinal direction obtained in the present work with Narendra for case 1 (a) and case 2 (b).

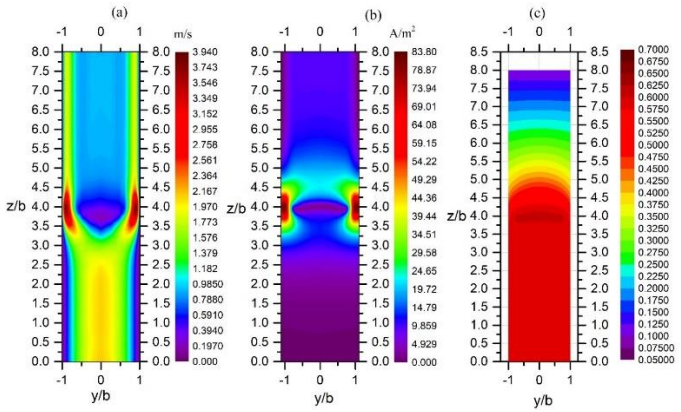

Fig. 3. Normalized velocity distribution (a), current intensity distribution (b) and normalized pressure profile (c) of case 2 on yz(x/b=0) plane.

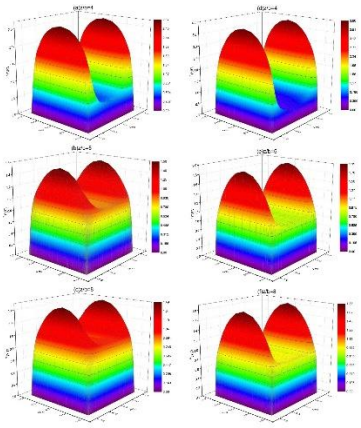

Fig. 4. The velocity profile at three axial locations viz, z/b=4, z/b=5, and z/b=8 (from top to bottom) for $\boldsymbol{C_w}$=0.1, $\boldsymbol{N}$=1000 and $\boldsymbol{Ha}$=50 (left) and $\boldsymbol{Ha}$=100 (right).

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