An MHD Study of the Behavior of an Electrolyte Solution Using 3D Numerical Simulation

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Introduction: This article considers a closed water circuit with square cross section filled with salt water, known as electromagnetic pump, where a magnet generates a magnetic field and electrodes generate the electric field in the flow. The movement is a consequence of the magnetohydrodynamic effect. From the flow movement and using simulations, it is possible to obtain a velocity profile as well as the Lorentz force and current density along de circuit and associate it with the magnetohydrodynamic phenomenon.

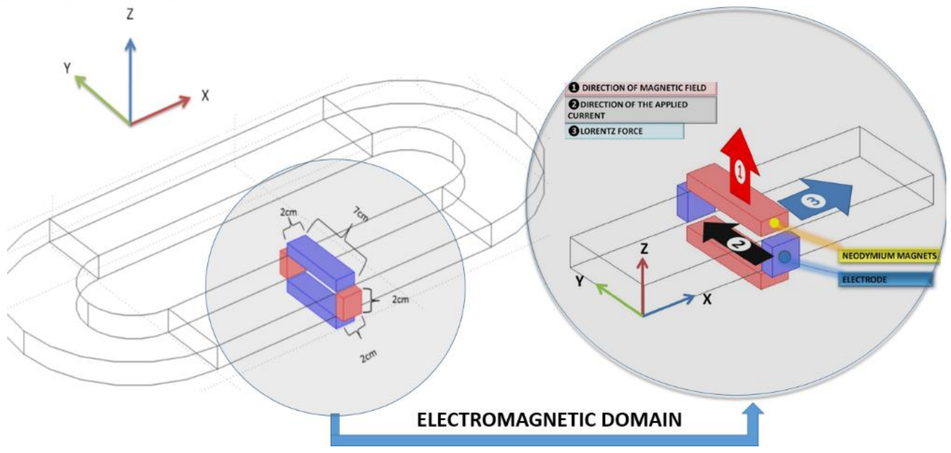

Figure 1. The MHD circuit

Computational Methods: The model has been derived from Navier-Stokes coupled with the Maxwell equations for a Newtonian incompressible fluid. The interaction between magnetic fields and current density generates a Lorentz force that drives the fluid through the channel. The 3D MHD equations were solved using the finite element method in COMSOL Multiphysics version 3.5a (2008)[1].

$$\rho\left(\mathbf{u}\cdot\nabla\right)\mathbf{u} = \nabla\cdot\left[-p\mathbf{I}+\left(\eta+\eta_T\right)\left(\nabla\mathbf{u}+\left(\nabla\mathbf{u}\right)^T\right)\right]+\mathbf{F} \quad (1)$$

$$\nabla\cdot\mathbf{u} = 0 \quad (2)$$

$$\mathbf{J} = \sigma\left[-\nabla\phi+\mathbf{u}\times\mathbf{B}\right] \quad (3)$$

$$\mathbf{F} = \mathbf{J}\times\mathbf{B} \quad (4)$$

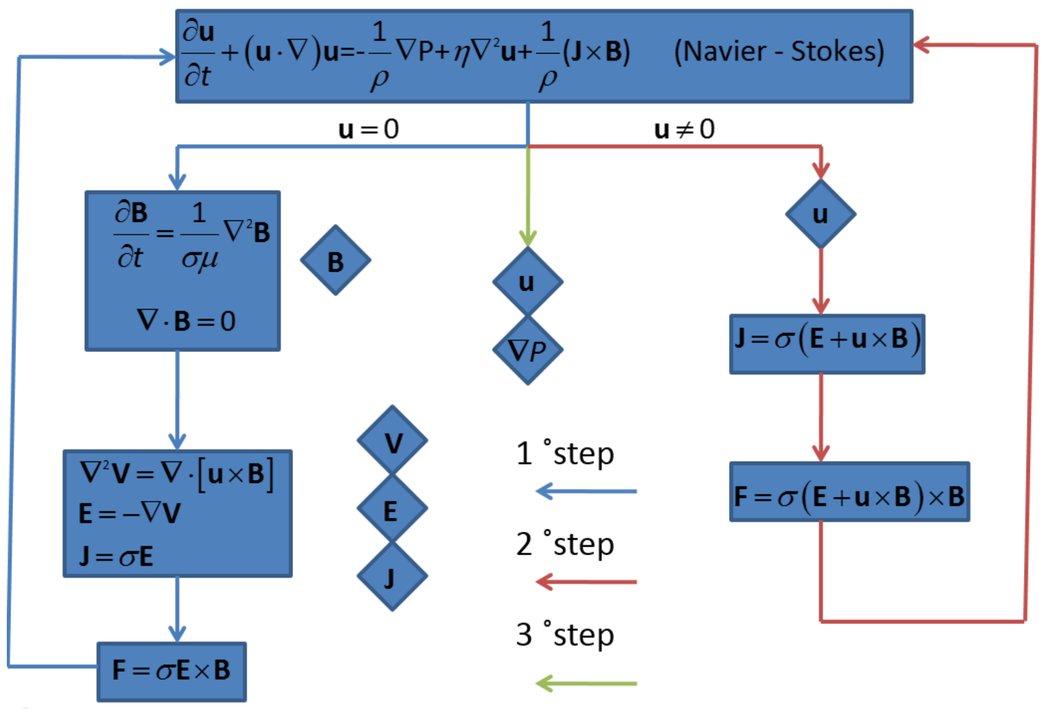

Figure 2. Solving process

Case	Voltage (V)	Velocity (m/s)	Lorentz (N/m³)
1	12	0.095	580
2	30	0.146	920

Table 1. Two simulations cases

Results: With COMSOL we were able to analyze the current density, Lorentz Force and the velocity pattern present in the MHD electromagnetic pump and compare with others works [2].

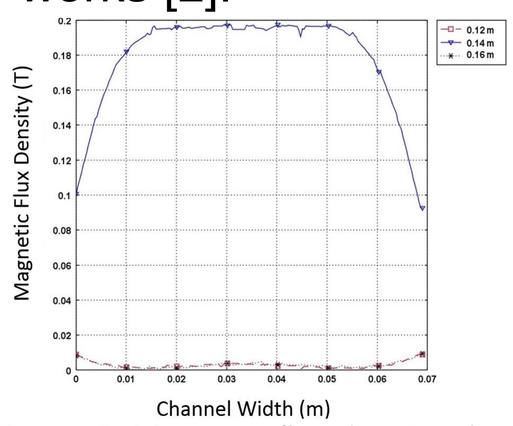

Figure 3. Magnetic flux density along the y-axis

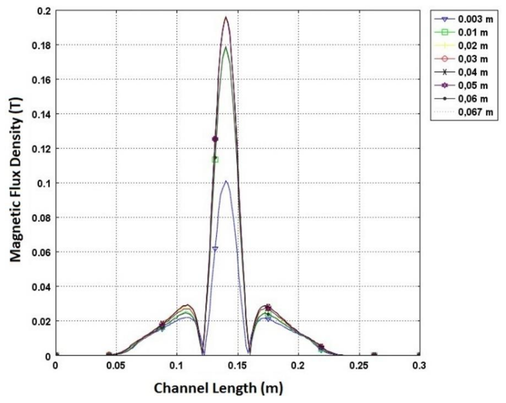

Figure 4. Magnetic flux density along the x-axis

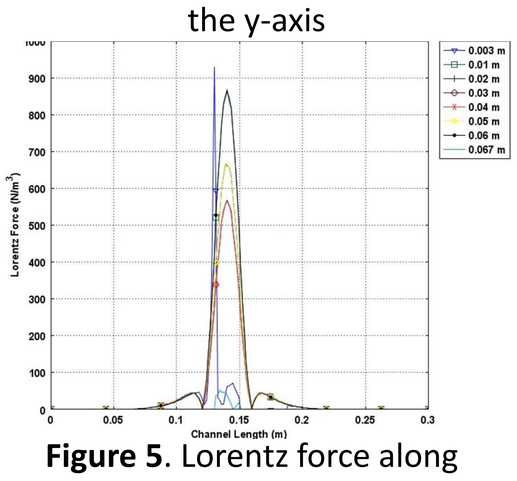

Figure 5. Lorentz force along the x-axis for at 30 Volts

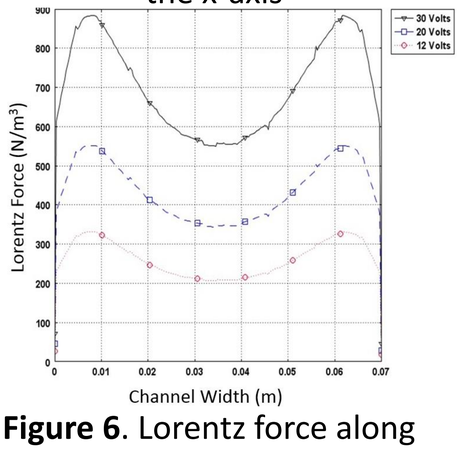

Figure 6. Lorentz force along the y-axis for three voltages

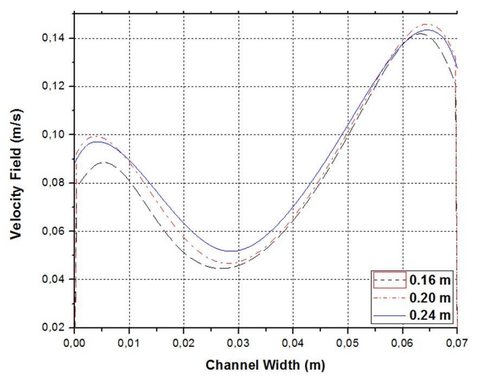

Figure 7. Velocity profiles (30 V)

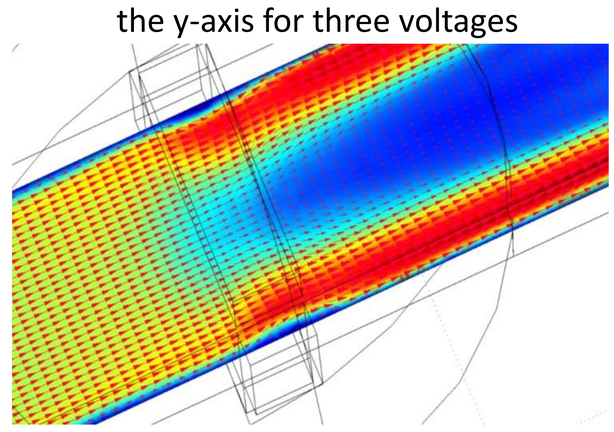

Figure 8. Velocity pattern (30 V)

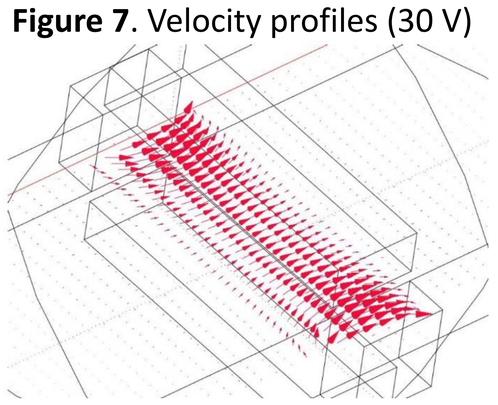

Figure 9. Lorentz force vectors

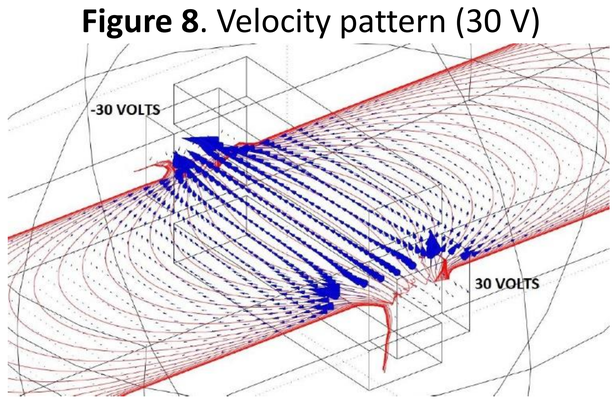

Figure 10. current vectors

Conclusions: Numerical simulations were carried out for salt water. MHD cases for different voltages were simulated using 3D finite element method, providing data from the MHD system, like Lorentz force intensity along the channel, current density around the fluid and magnetic field. An M-shaped velocity profile was observed in the flows.

References:

1. Kandev. N., Daoud, A., Electromagnetic DC pump of liquid aluminium computer simulation and experimental study, Fluid dynamics and materials processing, Vol. 224, No. 1, pp. 1-28 (2009)
2. Comsol Multiphysics., Modeling guide, Version 3.5a, pp. 1-580 (2008)

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