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

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Abstract

INTRODUCTION

Magnetohydrodynamics or simply (MHD) is a field of science that studies the movement of conductive fluids subjected to electromagnetic forces. Such a phenomenon brings together concepts of fluid dynamics and electromagnetism. Over the years, MHD has been encountered in a wide área of technological applications, from electromagnetic propulsion to biological devices. This article examines a rectangular closed circuit filled with an electrolyte fluid, known as electromagnetic pumping, where a permanent magnet generates a magnetic field and electrodes generate the electric field in the flow. The fluid conductor moves inside the circuit under 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 MHD phenomenon.

COMSOL MULTIPHYSICS

The MHD model circuit shown in (Figure 1) has been derived from the Navier Stokes equation (Fluid dynamics module) and coupled with the Maxwell equations for Newtonian incompressible fluid. Electric and magnetic components (AC/DC module) engaged in the test chamber assist in creating the propulsion of the electrolyte fluid. The channel is subjected to an externally magnetic field B_z, perpendicular to the fluid, produced by neodymium magnets. The channel´s plane and therefore the whole circuit is located at horizontal plane x-y and z=0. An external direct current is applied along the circuit, simulating the real power supply. The electromagnetic domain is delimitated by an air sphere. The 3D MHD equations were solved using finite method in COMSOL Multiphysics®. The electromagnetic forces that arise are due to the cross product between the vector density of induced current and the vector density of magnetic field applied. This is the Lorentz force.

RESULTS

Results are present of COMSOL 3D numerical MHD simulation. The goal is to relate the magnetic field with the electric field and the amounts of movement produced, and calculate de current density and fluid velocity profile. (Figure 2) and (Figure 3) shows the velocity profile along the channel for a 20 Volts direct current and the Lorentz force associated with this.

CONCLUSION

Numerical simulations were carried out for salty water. Many MHD cases for different voltages were simulated using 3D finite element method, providing interesting data from the MHD system, like Lorentz force intensity along the channel, current density around the fluid and magnetic field used to create the electromagnetic force. An u-shaped velocity profile and a m-shaped velocity profile were expected in the flows. (Figure 4) shown this peculiar profile, present in many others MHD experiments. Observing the interaction between the fields strengths, and density of the electrolyte fluid an optimal configuration for the flow velocity was determined and compared with others publications. With the data provided by simulations, the author was able to build a real DC pumping, using this device to simulate other experiments.

Reference

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Figures used in the abstract

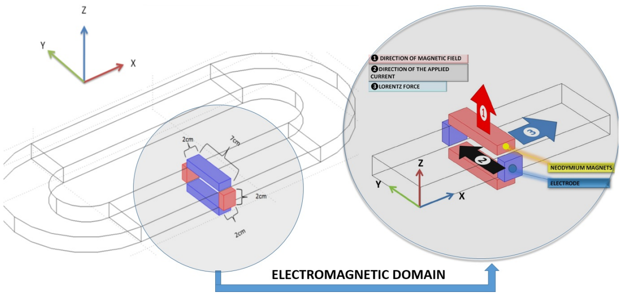

Figure 1: MHD model and geometry.

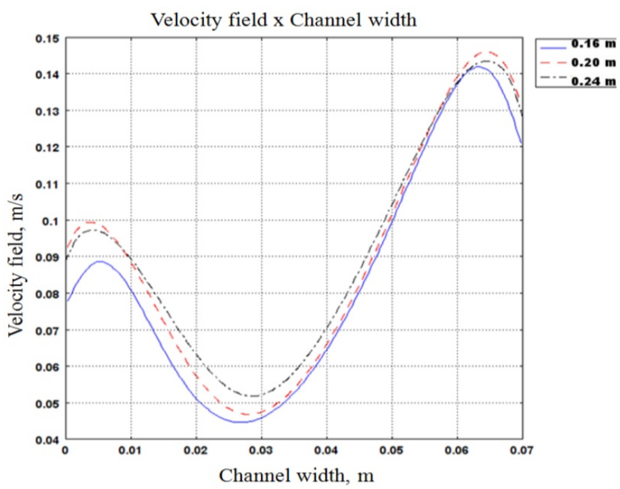

Figure 2: Velocity profile along the channel.

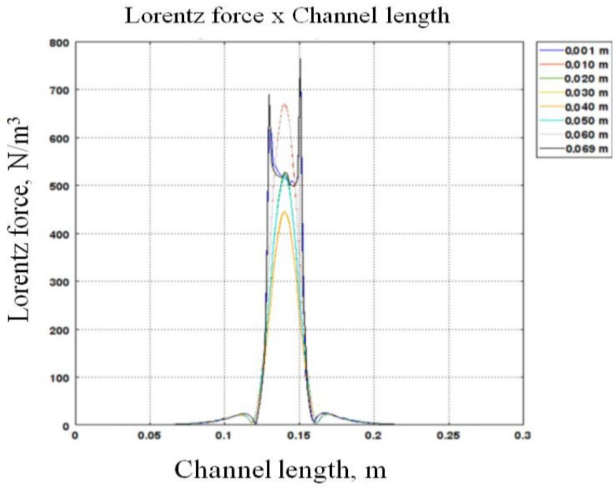

Figure 3: Lorentz force along the channel.

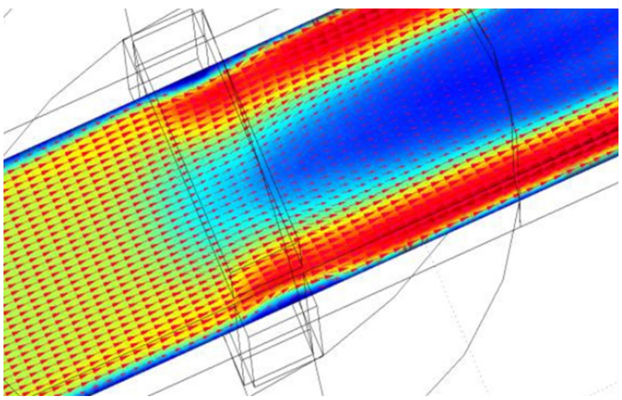

Figure 4: Velocity pattern.