International Journal of Multiphysics
Volume 18, No. 3, 2024
ISSN: 1750-9548

Simulation of Two-Dimensional Electromagnetic Analysis of a Conduction Magetohydrodynamic (MHD) Pump

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Received: 23/10/2023 ; Accepted: 21/06/2024

Abstract
In this paper we have studied the electromagnetic phenomena in a Magnetohydrodynamic (MHD) pump for the determination of the principal parameters such as the distribution of the magnetic potential vector magnetic induction by the finite volume method. The validation of the results with Ansys is presented.

Index Terms: Magnetohydrodynamic (MHD), Conduction pump, Electrode, Finite Volume Method**,** Ansys.

NOMENCLATURE

$\vec{H}$: Magnetic field, [A/m.]
$\vec{E}$: Electric field,[V/m].
$\vec{B}$: Magnetic induction, [T].
$\vec{D}$: Electric Induction, [c/m].
σ: Electric conductivity, [S/m].
ε: Electric permittivity, [F/m].
μ: Magnetic Permeability, [H/m].
V: Velocity of the fluid, [m/s].
$\vec{J}$, $\vec{J}ex$, $\vec{J}_a$: Current density , current source density, current density injected by electrodes ,[A/m²].

1. INTRODUCTION

The interaction of moving conducting fluids with electric and magnetic fields provides for a rich variety of phenomena associated with electro-fluid-mechanical energy conversion. Effects from such interactions can be observed in liquids, gases, [12,3,4,5,6]

Magnetohydrodynamic (MHD) is a scientific discipline which describes the behavior of a conducting fluid (Liquid or ionized gas) in the presence of electromagnetic fields, [4.5].

The MHD conversion is one of the applications of this discipline, it relates to the mechanical energy transformation of the movement of a fluid into electric power.

The aim of this article is to study the electromagnetic problem in a conduction MHD pump. The formulated problem is solved computationally by using a developing cod by finite volume method in matlab. Also, the comparison of the results with Ansys software is presented, [7,9].

The scheme of the MHD pump is shown in fig.1 The basic principle is to apply an electric current across a channel filled with electrically conducting liquids and a dc magnetic field orthogonal to the currents via permanent magnets, [1,3,].

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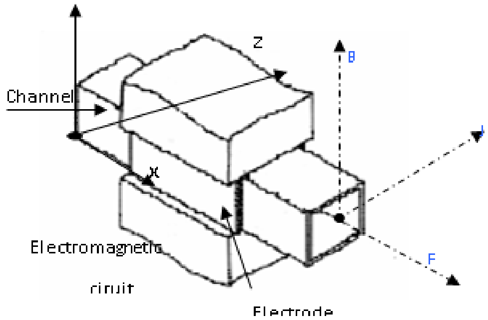

Fig.1. Scheme of DC MHD pump,[3].

2. GOVERNING EQUATIONS

The equations which describe the pumping process in the channel are the Maxwell's equations and the equations of the medium such as:

$$\vec{Rot}\vec{H} = \vec{J}; \quad (1)$$

$$\vec{Rot}\vec{E} = -\partial\vec{B}/\partial t; \quad (2)$$

$$Div\vec{B} = 0; \quad (3)$$

$$Div\vec{D} = 0; \quad (4)$$

$$\vec{B} = \mu \ \vec{H} \quad (5)$$

$$\vec{D} = \varepsilon \ \vec{E} \quad (6)$$

and the Ohm law :

$$\vec{J} = \sigma\left(\vec{E} + \ \vec{V} \wedge \vec{B}\right) + \vec{J}_{ex} \quad (7)$$

The electromagnetic force is given by:

$$\vec{F} = (\vec{J}_{ind} + \vec{J}_a) \wedge \vec{B} \quad (8)$$

The equations (1-6) can be combined in order to obtain the following equation:

$$\vec{Rot}(\frac{1}{\mu}\vec{Rot}\vec{A}) = \vec{J}_{ex} + \vec{J}_a + \sigma(\vec{V} \wedge \vec{B}) \quad (9)$$

With $\vec{Rot}\,\vec{A} = \vec{B}$;($\vec{A}$ is the magnetic vector potential).

After development in Cartesian coordinates:

$$\frac{1}{\mu}(\frac{\partial^2 A}{\partial x^2} + \frac{\partial^2 A}{\partial y^2}) = J_{ex} + J_a + \sigma\left(V\frac{\partial A}{\partial x}\right) \quad (10)$$

To solve this equation and to ensure the unicity of $\vec{A}$, we generally add the condition of Coulombs jauge of: $Div\vec{A} = 0$. This assumption is naturally checked in the two-dimensional configuration (2D).

3. NUMERICAL METHOD

There are several methods for the determination of the electromagnetic fields; the choice of the method depends on the type of the problem.

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In our work, we thus choose the finite volume method, its principle consists on subdividing the field of study (Ω) in a number of elements. Each element contains four nodes of the grid. A finite volume surrounds each node of the grid (Fig.2), [10,11].

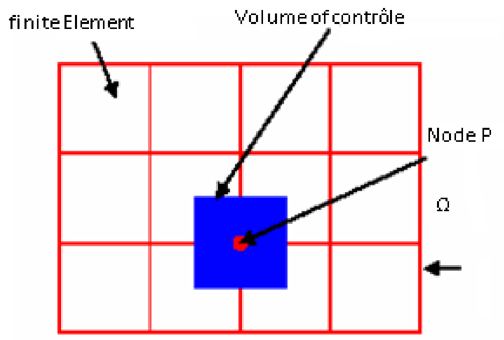

Fig.2 Grid of the domain.

In the two-dimensional case, the finite volume is limited by the interfaces (E, W, N and S), each principal node P is surrounded by four close nodes: the east E, the west W, following X, and two following Y, the north N and the south.

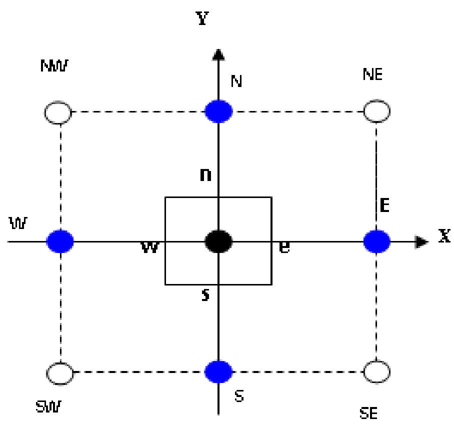

Fig.3. Description of finit volume

$$\int_w^e \int_s^n \left[\frac{1}{\mu} \left(\frac{\partial^2 A}{\partial x^2} + \frac{\partial^2 A}{\partial y^2} \right) \right] dx\, dy = \int_w^e \int_s^n (J_{ex} + J_a + \sigma V \frac{\partial A}{\partial x}) dx\, dy \qquad (10).$$

After integration, the final algebraic equation will be

$$a_p A_p = a_e A_e + a_w A_w + a_n A_n + a_s A_s + d_p \qquad (11)$$

With: $a_e = \dfrac{\Delta y}{\mu_e (\delta x)_e}$, $a_w = \dfrac{\Delta y}{\mu_w (\delta x)_w}$, $a_n = \dfrac{\Delta x}{\mu_n (\delta y)_n}$, $a_s = \dfrac{\Delta x}{\mu_s (\delta y)_s}$,

$$a_p = a_e + a_w + a_n + a_s;$$

$$d_P = (J_{ex} + J_a).\Delta x \Delta y$$

4. Application and Results

We consider the following figure which represents the transverse section of pump MHD with the following characteristics:

-The liquid in the channel is mercury with the conductivity $\sigma_{mercure}$ =1.66*10^6 [S/m] ;

- The current source density is Jex=1.8*10^6 [A/m²]
- The current density in the electrodes is Ja=1.5*10^6 [A/m²].

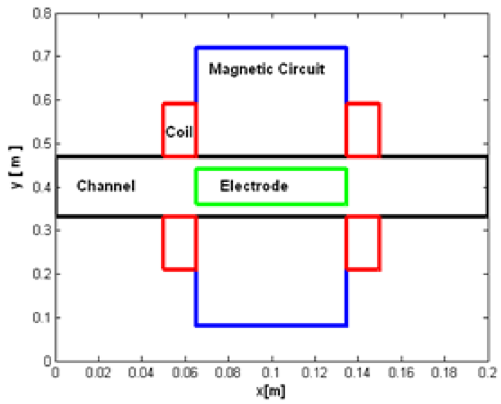

Fig4. A conduction MHD pump configuration

Generally, an electromagnetic device has several materials, which some have nonlinear characteristics. In addition, the electromagnetic phenomena change strongly within the structure

The ferromagnetic materials, which are very permeable, allow the circulation of a significant magnetic flux.

The law of the ferromagnetic materials is the curve B (H) which expresses the nonlinear relation which exists between magnetic induction and the magnetic field.

In this case the reluctivity $v_m = 1/\mu$ becomes variant curve B(H) and it is as follows.

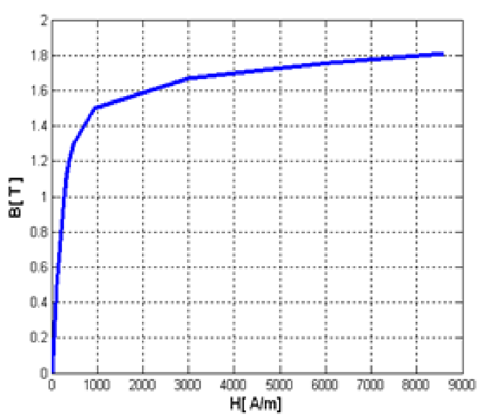

Fig5 . B(H) curve

The figure (6) represents the distribution of equipotential lines in the MHD pump.

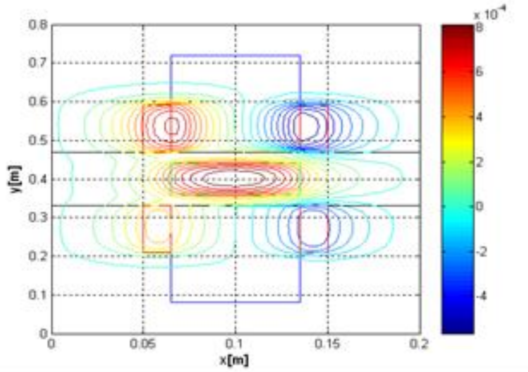

Fig.6 Equipotential lines in DC pump MHD

The figures (7) and (8) represents the distribution of the magnetic vector potential and the magnetic induction in the cannel of the MHD pump.

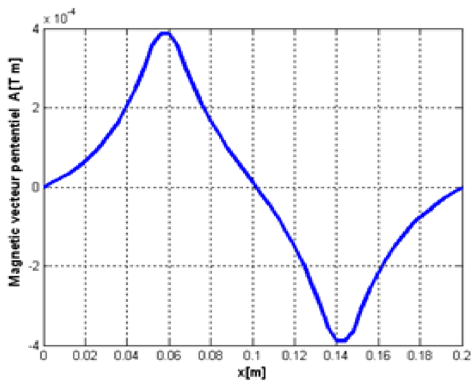

Fig 7. Magnetic vector potential in pomp

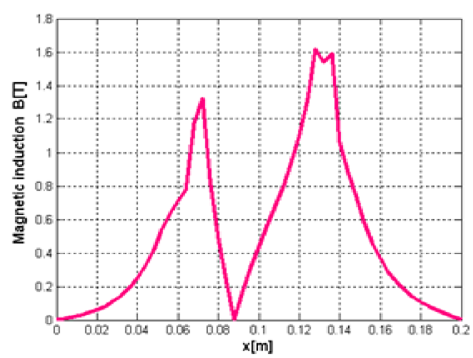

Fig.8 Magnetic induction in the pump

5. VALIDATION OF THE RESULTS BY ANSYS

5.1 PRESENTATION OF THE SOFTWARE.

Software ANSYS is a tool for simulation for the calculation of the electromagnetic fields of the physical systems. It is a physical software, it allows the electromagnetic, hydrodynamic and thermal analysis.

To carry out simulations by this software, we must follow the following staps:

- Definition of the type of analysis (electromagnetic, thermal, or mechanics of the fluids);
- Entry of the values of the parameters (characteristic physics of materials and geometrical parameters);
- Definition of the used elements;
- Creation of the geometry of the model, and entered of different the types of materials
- Creation of the grid;
- Entered of the boundary conditions and excitations (power sources);
-
- Resolution;
- Visualisation of the results.

The results of simulation of to conduction MHD pump, in static mode and in the nonlinear cases obtained by ANSYS are represented below (geometry, boundary conditions of Dirichlet and corresponding grid).

The ANSYS also allows an automatic grid of a the geometry 2d.The grid of the selected analyzed field is a square. We can refine the grid in any zone of the structure.

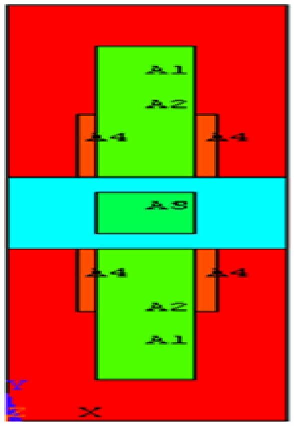

Fig9. A conduction MHD pump configuration

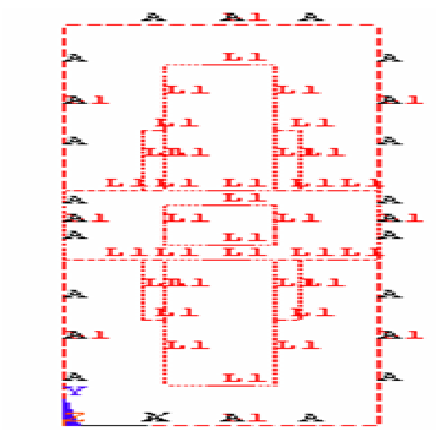

Fig10 Boundary conditions

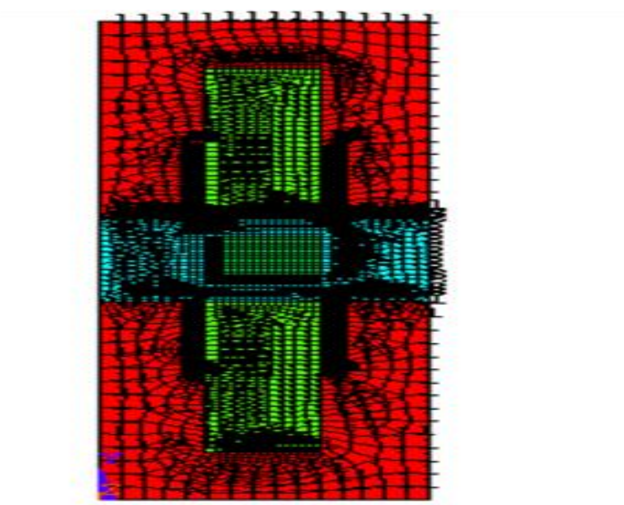

Fig 11 Grid of the pump

The results from the ANSYS are exploited to represent the equipotential lines, the magnetic potential vector and the distribution of magnetic induction in pump MHD.

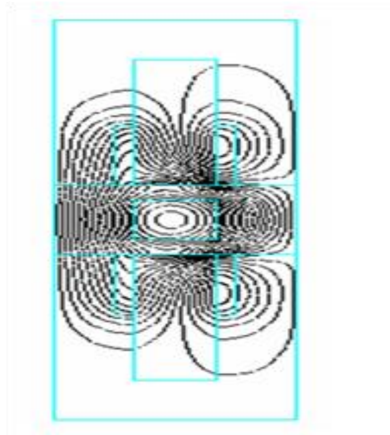

Fig12 Equipotential lines in DC pump MHD.

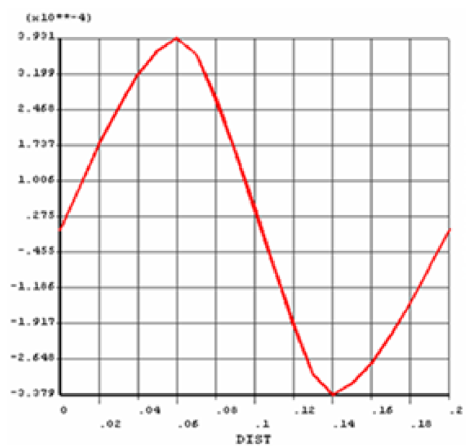

Fig 13. Magnetic vector potential in pomp

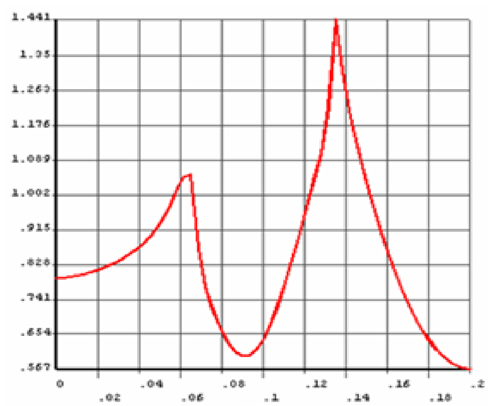

Fig.14 Magnetic induction in the pump

5.2 Interpretation of results

According to the results obtained we note that resultes simulated by MATLAB are the same to those simulated by ANSYS.

6. CONCLUSION

In this article, we have studied the electromagnetic phenomena in 2d of pump MHD with conduction by taking account of the movement of the fluid. Various characteristics such as the distribution of the magnetic potential vector, magnetic induction in the conduction pump MHD with to software, MATLAB and ANSYS can see

According to the results obtained we note that resultes simulated by MATLAB are the same to those simulated by ANSYS.

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