Thermomagnetic Convection Pattern is Analyzed in an Annular Space under a Non – Uniform Magnetic and Thermal Field

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***Abstract*: In this paper, the thermomagnetic convection of magnetic fluid which has more thermal sensitivity when it is compared with a non-uniform magnetic field.The results are analyzed and the isotherms, streamlines at different interval points are drawn.As a result ,in case of $\nabla T \times \nabla H \neq 0$ thermomagnetic convection pattern is found to be produced,the convetion pattern is depends on the electric current distribution. In that diagram clockwise, anti-clockwise and concentric circles shows that the changing of convection pattern due to electric current at various points.**

***Keywords*: Magnetic fluid, Ferro fluid, Thermomagnetic convection.**

I. Introduction

A two dimensional thermomagnetic convection pattern of magnetic fluid possessing internal spin and the relaxation of magnetization with high thermal sensitivity is numerically analyzed under a non-uniform magnetic and thermal field. The thermomagnetic convection pattern of magnetic fluid within an annular space is numerically investigated under a different position of an electric current wire is fixed. The electric current wire is placed in a different positioning the annular space the circulation flow is produced. It shows that the thermomagnetic convection pattern is controlled by changing the relative direction of an electric current. Therefore the convection pattern is depends on changing various direction of an electric current in an annular space.

II. Preliminaries

2.1Fluid Dynamics

Fluid dynamics is the branch of applied science that is concerned with the movement of liquids ,gases and plasma. It has a two branches that is fluid mechanics and fluid statics, fluid mechanics is the study of fluids and how forces affect them,and the fluid statics, which deals with fluids is at rest. Fluid flow is dependent on the intrinsic properties of matter itself,that is compressibility,viscousity and density.

Scientists in several fields study fluid dynamics. It has a several methods for studying the movements and evolution of ponds, nanospace, aerospace stars, ocean currents, ponds, astrophysics, weather patterns, plate tectonics and even blood circulation. Fluid dynamics has some important applications it include rocket engines, wind turbines, oil,space , limnology, pipelines and air conditioning systems.

2.2Fluid

The term FLUID is a substance that flows. This is divided into two kinds

- LIQUIDS
- GASES

2.3Thermomagnetic Convection

The heat is transferred by using ferrofluid, therefore the heat and mass transport in such magnetic fluid can be controlled using an external magnetic field. An external magnetic magnetic field is imposed on a ferrofluid with varying magnetic field due to a temperature gradient as a result in a non uniform magnetic body force which tends to thermomagnetic convection.

2.4 Convection

Heat can be transferred through a gas or liquid by the hotter material moving into a cooler area when convection take place,that is heat is transferred by the circulation of currents from one region to another. It is caused by an external force of gravity.

2.5 Magnetization

The process in which magnetic materials attains magnetism is called magnetization. The magnetization are by burning magnetic materials near the magnetic field its producing an electricity.

2.6 Magnetic Field

A magnetic field is a field that is created by moving electric charges and magnetic dipoles, and it is exert a force on other nearby moving electric charges and magnetic dipoles in the magnetic field.

2.7 Isotherms

An equal temperature at a given date or time on a geographic map. Itis termed as isotherms.

2.8 Electric Field

An electric field is a force that surrounds electric charges that attract or repels other electric charges. The direction of the force that is exerted on a negative charge is opposite that which is exerted on a positive charge. Because an electric field has both magnitude and direction, the direction of the force on a positive charge is an the direction of the electric field.

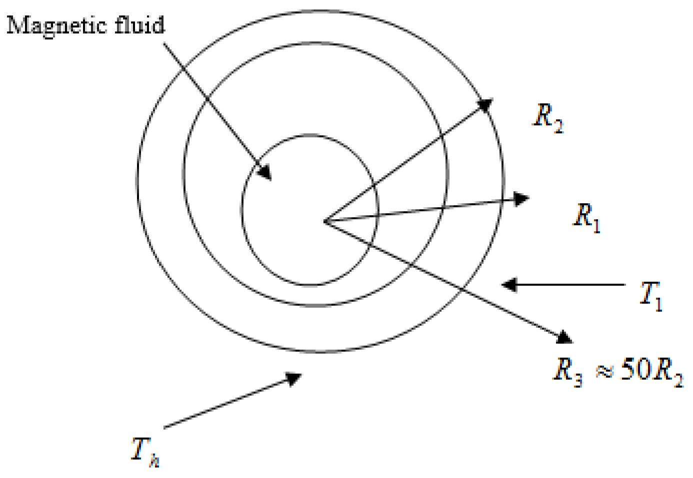
2.9 Magnetic Fluid

A hypothetical fluid is formed in an magnetic phenomena.It is an mixture of finely divided iron with oil or other suitable liquid that is increase in viscousity . Its tends to an strong magnetic field.

III. Analysis

3.1 Physical Model of Thermomagnetic Convection Pattern

Two-dimensional thermomagnetic convection is produced in an annular space under a non uniform magnetic field is analysed. Where a conductive electric wire of radius R_0 with a direct current I_0 is placed in the center of an annular space filled with a magnetic fluid of magnetic permeability μ_0 . Assumed that magnetic fluid is strongly magnetized by a magnetic field H due to an external magnetic fluid from an electric wire current and an induction magnetic field of the magnetic fluid,Thus the magnetic fluid is assumed to be at rest up to an time $t=0$ with a uniform temperature T_P andat $t>0$ a half part of the outsidecircumference is assumed to be fixed at a high temperature(T_h) and the rest half part of the outside circumference at a low temperature(T_I).



It follows the condition

The radius of wire is smaller when compared to the inside circle($R_0 << R_1$)

The effect of magnetic field within the distance $50R_2$

The magnetic permeability of magnetic fluid is equal to that of vacuum

The magnetic fluid in an annular space is incompressible fluid.

3.2 Governing Equation of an Incompressible Magnetic Fluid in Thermomagnetic Convection pattern

The continuity equation is

$$\nabla . v = 0$$

The momentum equation of neglecting gravityforce is

$$\rho \frac{Dv}{Dt} = -\nabla p + \eta \nabla^2 v + \nabla .(BH) + \frac{I}{t_s} \nabla \times (\Omega - \omega)$$

Where t is time, v velocity, ρ mass density of magnetic fluid , p pressure , η viscousity of magnetic fluid is absence of a magnetic field in an annular space, I: average inertia moments of particles per unit volume , t_S : the relaxation time of internal spin rotation in magnetic filed ,H:magnetic induction, Ω : internal spin rate, ω : effective rate of rotation of a fluid element

The internal angular momentum equation is

$$I \frac{D\Omega}{Dt} = \gamma I \nabla^2 \Omega - \frac{I}{t_s} (\Omega - \omega) + \mu_0 M \times H$$

Where gamma is a dissipation coefficient of internal spin moment,M magnetization of the magnetic fluid. The magnetization relaxation is

$$\frac{D\Omega}{Dt} = \Omega \times M - \frac{1}{t_b} (M - M_0)$$

Where t_b is the relaxation time of the particle rotation by Brownian rotation motion, M is the equilibrium magnetization of the magnetic fluid.

We use the hybrid difference scheme to solve the equation .Therefore the discretised equation is given by

$$a_p = a_w + a_e + a_s + a_n + a_b + a_t + \Delta F$$

The Maxwell's equation for a non-conducting fluid with no displacement current becomes

$$\nabla \times H = 0,\ \nabla . B = 0$$

3.3 Apply finite Volume method for two dimensional diffusion problem

The methodology is used to deriving the discretised equation for two dimensional steady state equation

$$\frac{\partial}{\partial x}\left(\Gamma \frac{\partial \phi}{\partial x} \right) + \frac{\partial}{\partial y}\left(\Gamma \frac{\partial \phi}{\partial y} \right) + S\phi = 0$$

So that R= $R_1 = \nabla y$, and R= $R_2 = \nabla x$,we obtain

$$\left[\Gamma_R A_R\left(\frac{\partial\phi}{\partial x}\right)_R - \Gamma_{R_1} A_{R_1}\left(\frac{\partial\phi}{\partial x}\right)_{R_1}\right] + \left[\Gamma_R A_R\left(\frac{\partial\phi}{\partial x}\right)_R - \Gamma_{R_2} A_{R_2}\left(\frac{\partial\phi}{\partial x}\right)_{R_2}\right] + \bar{S}\nabla V = 0$$

Therefore the above equation represents the balance of the generation of ϕ in a control volume and the fluxes through its cell faces.

By using the above concepts we can find the convection pattern.

3.4 Coordinate System

Cartesian coordinate (x,y) is fixed in the center of an annular pipe, the y-axis being vertically upward, relationship between cylindrical and Cartesian coordinates is

$$x + iy = \mathrm{Re}^{io}$$

Where the hybrid finite difference method is applied for solving the equation. It is express in fourier series the circumferential theta direction.

3.5 Equation of the distribution of magnetic field

The magnetic induction stream functions are

$$B_{ix} = \frac{\partial \psi_i^m}{\partial y}, \quad B_{iy} = -\frac{\partial \psi_i^m}{\partial x}$$

3.6 Boundary Conditions

The boundary conditions used are as follows

At R=, No-slip,No-spin, and thermal insulation:

$$[V]_{R=R_1} = 0,\ [\Omega]_{R=R_1} = 0, \left(\frac{\partial T}{\partial R}\right)_{R=R_1} = 0$$

At R= No-slip,No-spin, and Dirchlet temperature condition:

$$[V]_{R=R_2} = 0, [\Omega]_{R=R_2} = 0$$

$$T(\theta, R_2) = T_h \quad \text{for} \quad \theta \in \left(\frac{\pi}{2}, \frac{3}{2}\pi\right)$$

$$T(\theta, R_2) = T_1 \ \text{for} \quad \theta \in \left[0, \frac{\pi}{2}\right] \cup \left[\frac{3}{2}\pi, 2\pi\right]$$

The normal components of the magnetic induction and the tagential components of the magnetic field are continuous across the interface between the dissimilar regions,

at R= R_1 : $[B_1]_n = [B_2]_n$, $[H_1]_t = [H_2]_t$

at R= R_2 : $[B_2]_n = [B_3]_n$, $[H_2]_t = [H_3]_t$

where the subscript n and t denote normal and tagential component. Then the boundary condition of equation is

$$\overline{\varphi_1^m} = 0, \frac{\partial \varphi_1^m}{\partial R} = 0 \ (R=0)$$

3.7 Result

Assuming that the magnetic particle of magnetic fluid is iron oxide,and that the carrier liquid is hydrocarbon, the following constants and parameters of magnetic fluid are used. The circulating flow is produced depends upon the various position of an electric current wire is fixed.Therefore the thermomagnetic convection pattern is depends upon the changes in electric current in magnetic field under a non uniform magnetic and thermal field.The isotherms ,streamlines at different intervals produced a circulating pattern like clockwise, anticlockwise and concentric circles are analysed.

3.8 Magnetic Body Force Of Magnetic Fluid

Since the relaxation time $t_s(10^{-11}s)$ of internal spin rotation ,inertia spin moment is very small, therefore the equation become

$$\frac{I}{t_s}(\Omega - \omega) = \mu_0 M \times H$$

And substituting we get momentum equation:

$$\rho \frac{Dv}{Dt} = -\nabla \rho + \eta \nabla^2 v + \mu_0 (M.\nabla) H$$

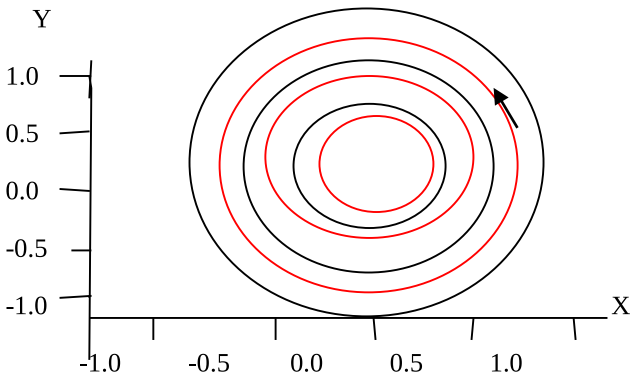
The curl of the magnetic body force is given by

$$\nabla \times \mu_0 (M.\nabla) H = \mu_0 \frac{\partial X}{\partial T} [\nabla T \times (H.\nabla) H]$$

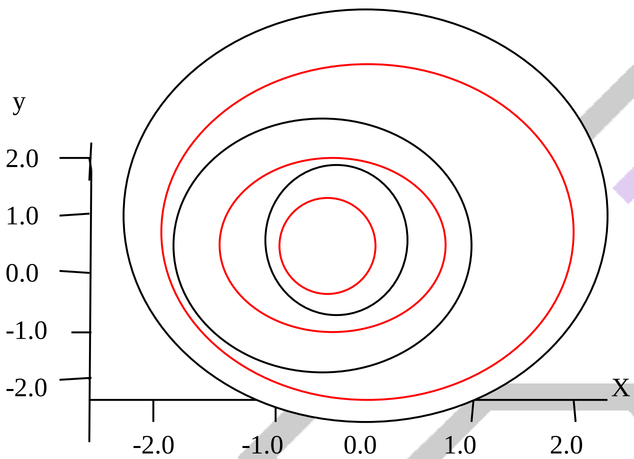
Therefore ,the thermomagnetic convection is derived in the gravity free space as $\nabla T \times \nabla |H| \neq 0$

3.9 Numerical Result

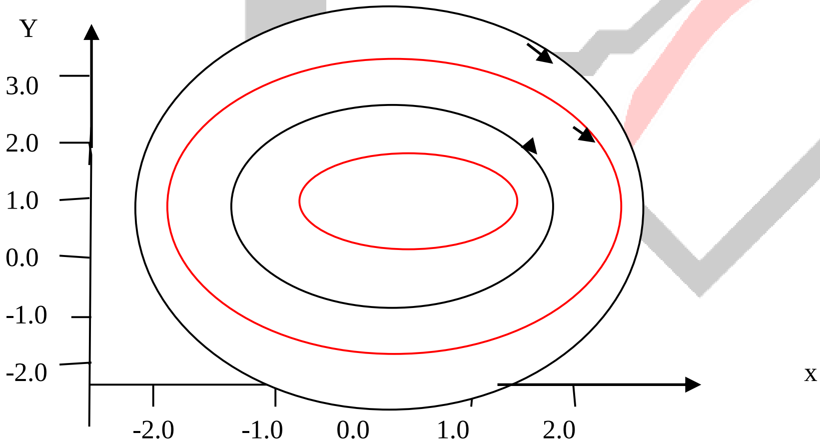
In this case the isotherms, streamlines and dimensionless magnetization field strengths with the position of electric current wire varies are displayed. It shows that the convection pattern depends on changing relative direction of an electric current.Thus it is found that thermomagnetic convection is controlled by changing relative direction of temperature gradient to that of a magnetic field. If the electric current wire values i,e the values of (x,y) is different the direction of circulating flows is different .Therefore the circulating flow are produced. Especially the position of electric current wire is different from centre or in changing in various direction the circulation is produced in different direction like clockwise , anticlockwise, and concentric circles are produced.Thus the thermomagnetic convection is produced by changing an electric current.



For isotherms at an interval 1.0, stream lines 1.0,and the dimension of magnetization field strengths at an interval 1.0 from 0.002 to 0.02 in this the case of an electric current wire is fixed at (x,y)=(0,1.0), where the direction of flow is anticlockwise .



For isotherms at an interval 2.0, stream lines 2.0,and the dimension of magnetization field strengths at an interval 2.0 from 0.002 to 0.02 in this the case of an electric current wire is fixed at (x,y)=(0,2.0), where the direction of flow is concentric circles.



For isotherms at an interval 3.0, stream lines 3.0,and the dimension of magnetization field strengths at an interval 3.0 from 0.002 to 0.02 in this the case of an electric current wire is fixed at (x,y)=(0,3.0), where the direction of flow is anticloclwise.

IV. Conclusion

Thus this paper gives a brief discussion of thermomagnetic convection of fluid under the influence of magnetic field. The various intervals shows the variations of the electric current and the circulation pattern changes are produced. Therefore a non uniform of temperature and a spatially non – uniform of external magnetic field are required so that $\nabla T \times \nabla H \neq 0$ Thus the various circulating flows are discussed in the form of an magnetic circles.Thus the convection pattern are analysed in the form of circles at various points. Therefore the convection pattern is depends upon the relative changes of electric current are analysed .

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