ISBN: 978-81-941253-2-7

AN INTRODUCTION TO MAGNETOHYDRODYNAMIC FLOW

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ABSTRACT

In this chapter, an introductory study on magnetohydrodynamics has been proposed. MHD is the study of motion of an electric conducting fluid with presence of magnetic field. It is found by coupling between the Navier-Stokes equations for fluid dynamics and Maxwell's equations for electromagnetism. This study introduces the Maxwell's equation and N-S equations and then the mathematical modeling of MHD derived by coupling these two. Also, the vorticity equation has been derived from N-S equation. Finally, some applications of MHD flow has been described, i.e., in industrial processes, medical treatments, geophysics, astrophysics etc.

Keyword : magnetohydrodynamics flow, Maxwell's equations, Navier-Stokes equations

INTRODUCTION

This is a branch of fluid mechanics which deals on the study of motion of an electric conducting fluid with presence of magnetic field. It a most relatively and important branch of fluid mechanics. Momentum of conducting fluid with magnetic fields creates an electric current inside the fluid. That magnetic field bring to bear a force which is known as "Lorentz Force". Solid or fluid materials when passing through the magnetic field, that time its acquaintance with an electromagnetic force. Plasmas, liquid metals, salt water etc. are examples of these types of fluid. The word Magnetohydrodynamics is the combination of three words as like 'magnet' which stands for magnetic field, 'hydro' stand for liquid and 'dynamics' stands for movement.

In 1942, Hannes Alfven was the first to introduce the term "MAGNETOHYDRODYNAMICS". He described astrophysical phenomena as an independent scientific discipline.He was awarded Nobel prize in physics in 1970 for his work on this field.The official birth of incompressible fluid Magnetohydrodynamics is 1936-1937. Hartmann and Lazarus performed theoretical and experimental studies of MHD flows in ducts.The governing equations are indicating the motion of conducting fluid in a magnetic field i.e, the couple of both "Navier-Stokes equation of fluid" and "Maxwell's equation of electromagnetism".

THE GOVERNING EQUATIONS

By considering electromagnetism and fluid dynamics, we can derive the governing equations for MHD flow. We have to consider "non-magnetic", "conducting", "Newtonian Fluid" with "uniform kinematic velocity" i.e $\nu = constant$ and incompressible flow.

Lets consider the Maxwell's Equations,

$$\nabla \times \boldsymbol{B} = \mu \boldsymbol{J} \qquad \nabla . \boldsymbol{J} = 0 \qquad (1)$$

The Faradat's Law is,

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t} \qquad \nabla . \boldsymbol{B} = 0 \qquad (2)$$

Ohm's Law and the Laplace forces is,

$$\boldsymbol{J} = \sigma(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}) \qquad \boldsymbol{F} = \boldsymbol{J} \times \boldsymbol{B} \qquad (3)$$

By combining above, we get a transformation equation for ***B***,

$$\frac{\partial \boldsymbol{B}}{\partial t} = -\nabla \times \boldsymbol{E}$$

$$= -\nabla \times \left(\frac{\boldsymbol{J}}{\sigma} - \boldsymbol{v} \times \boldsymbol{B}\right)$$