MHD

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1 Introduction

Magnetohydrodynamics or MHD is the motion of magnetized fluids. One magnetized fluid that we are concerned with in this paper is a ferrofluid. a ferrofluid contains ferromagnetic particles in a carrier fluid. It is very easy to just say that a ferrofluid will align and move with a magnetic field. If it were up to me, I would leave it at that. However, in order to understand this world more we need to delve deeper into MHD. To have a coherent understanding of MHD, we need to learn how fluid dynamics and electricity magnetism (EM) fit together. In this paper we shall explore fluid dynamics, EM, how fluid dynamics and EM come together to model MHD, and specific properties of ferrofluids and how they are made.

We first need to define a few things for our equations.

1. $\rho =$ mass density
2. $\vec{u} =$ flow velocity
3. $P =$ pressure
4. $\sigma =$ charge density
5. $\vec{J} =$ current density
6. $\vec{E} =$ electric field
7. $\vec{B} =$ magnetic field

Essentially we will take a fluid motion equation that looks like $F = ma$ and an EM equation that looks like $F = ma$, and put them together to get an equation of motion for our ferrofluid. One way to approach this problem is by considering conservation of mass. We use the equation $d\rho/dt = -\nabla\dot{(}\rho\vec{u})$ to show that the changing mass density is dependent upon the divergence of the mass density and the flow velocity. We can then use conservation of momentum to get an equation of the form $\rho(d\vec{u}/dt + \vec{u}\dot{\nabla}\vec{u}) = -\nabla p - \nabla\Pi + \vec{F}$. This momentum depends on pressure, viscous stress, and any other forces like gravity. This is the Navier-Stokes eqation for fluid motion. Viscous stress is a frictional force inside the fluid from certain parts of the fluid flowing opposite directions.

Insert picture HERE

We will for right now move on the EM portion. The evolution of of a magnetic field can be shown by $d\vec{B}\,/dt = -\nabla \times \vec{E}$ This is one of maxwells equations. Usually we have $\nabla \times \vec{E}\, = 0$. But this is only the case with static charges. When the charges start moving, we get a current and our above equation.

need to learn more things

Temperature is a critical consideration when it comes to MHD. In order for the colloidal suspension to remain stable the magnetic particles generally have to be approximately 10 nm in diameter. when they are this size they have only one magnetic domain. These particles then feel an attraction to each other. To stop this attraction to each other we must add a repulsive interaction. We can then charge the particles to give them a repulsive electrostatic force.

Making ferrofluids. most common magnetic particles in ferrofluids are megnetite and maghemite.

Vorticity is a property of fluids. It essentially measures the curl of a fluid. Often times, vorticity arises from friction of the fluid against the fluid container. You could imagine a river that is flowing past you. If there are no impedences, the river will be flowing the fastest in the center and the slowest near a the riverbanks. If you were to throw a stick into the river, the stick would spin because the river has curl. Vorticity can be generated by thermomagnetic interaction even in the absence of viscosity (think of convection). ferrohydrodynamics- the fluid dynamic and heat transfer processes associated with the motion of incompressible, magnetically polarizable fluids in the presence of magnetic field and temperature gradients. strong coupling is occurs when the polarization is field and temperature dependent.

charged particles are introduced into a fluid. When this fluid is placed within a magnetic field, the particles slip relative to the fluid and transmit drag to it. This is what causes the whole fluid to move. This is of scientific interest because in zero gravity we cannnot prime rocket pumps. We can potentially add charged particles to the fuel and use a EM field to move the fluid.

Still very choppy... I'm trying to figure out how to go about explaining all this stuff. I think I am getting a handle on the derivation however. I found a very nice video. https://www.youtube.com/watch?v=Mj2PuiNnubs. I think if I reread the first paper now, I will have a better grasp.