Numerical Analysis of Different Magnet Shapes on Heat Transfer Application using Ferrofluid

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Introduction: A magnetic colloid, also known as a ferrofluid, is a colloidal suspension of single-domain magnetic particles with typical dimensions of about 10*nm*, dispersed in a liquid carrier. Since the 1960, when these materials were initially synthesized, their technological applications are finding new directions. A ferrofluid is a temperature sensitive magnetic fluid which means that its magnetization is function of temperature. In this numerical analysis has done, In which the study of different magnet shapes are studied which shows the effect of magnetic field on ferrofluid and different parameters related to that like temperature, velocity and Heat transfer were evaluated. The experimental setup is shown in figure 1.

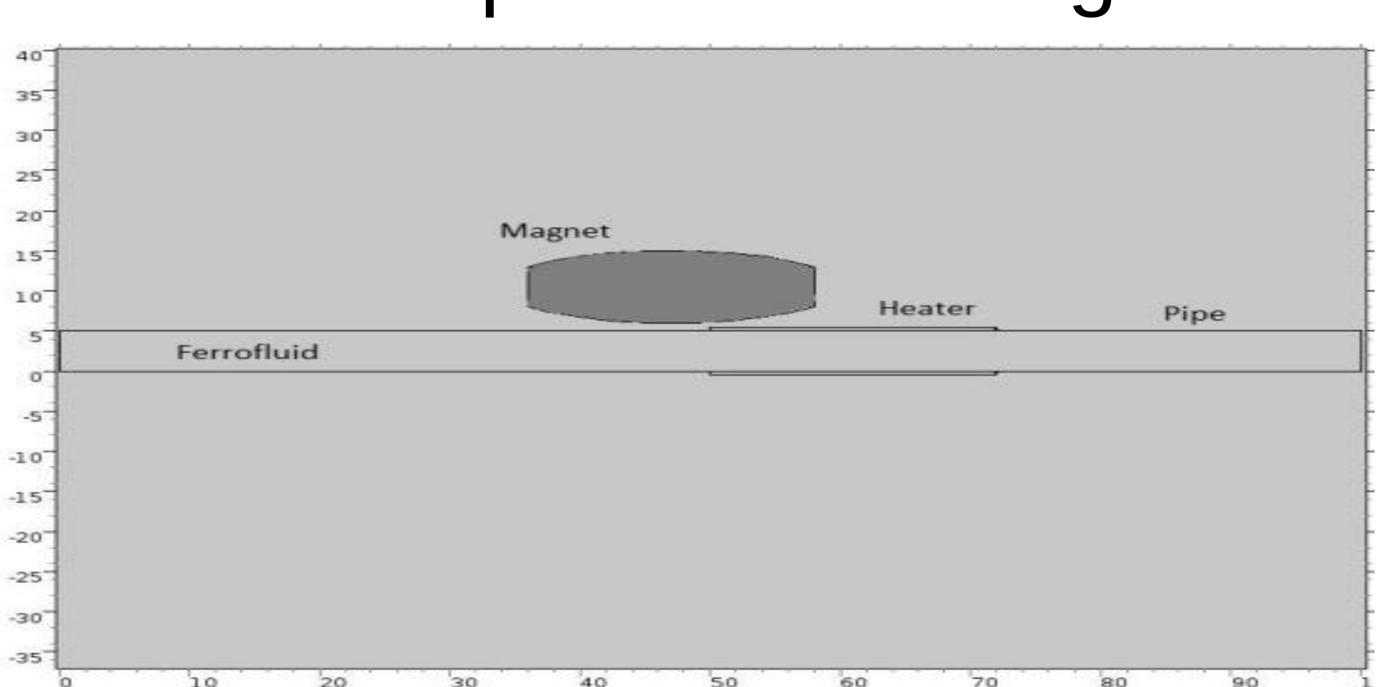

Figure 1. Different component of setup

Computational Methods: Numerical analysis was done using COMSOL Multiphysics by coupling of physics.

- Maxwell's equations:

$$\nabla \times \mathbf{H} = 0$$
$$\nabla . \mathbf{B} = 0$$

- Momentum equation :

$$\frac{d\rho}{dt} + \rho \mathbf{u} \nabla \mathbf{u} = \nabla\left[-p\mathbf{I} + \nabla . \mu(\nabla \mathbf{u} + (\nabla \mathbf{u})^T)\right] + (\mathbf{M}\nabla)\mathbf{B}$$

- Fourier equations :

$$\rho C_p\left(\frac{dT}{dt} + \mathbf{u}.\nabla T\right) = k\nabla^2 T + \mu\phi - \mu_0 T \frac{\partial M}{\partial T}((\mathbf{v}.\nabla)\mathbf{H})$$

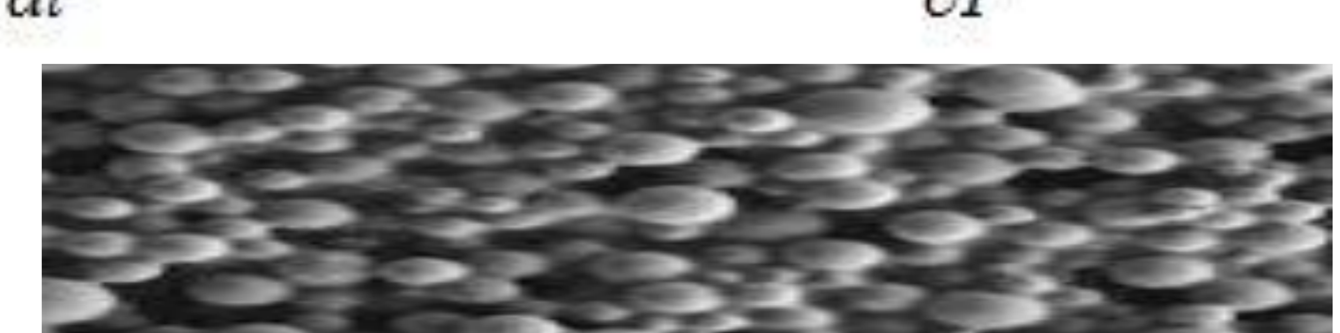

Figure 2. Microscopic image of ferrofluid

Results & Discussions: In this experiment, the favorable results achieved with convex shape magnet by calculating the parameters like Velocity, Temperature and Heat Transfer, by combined effect of temperature gradient and magnetic force which enables the flow of magnetic fluid.

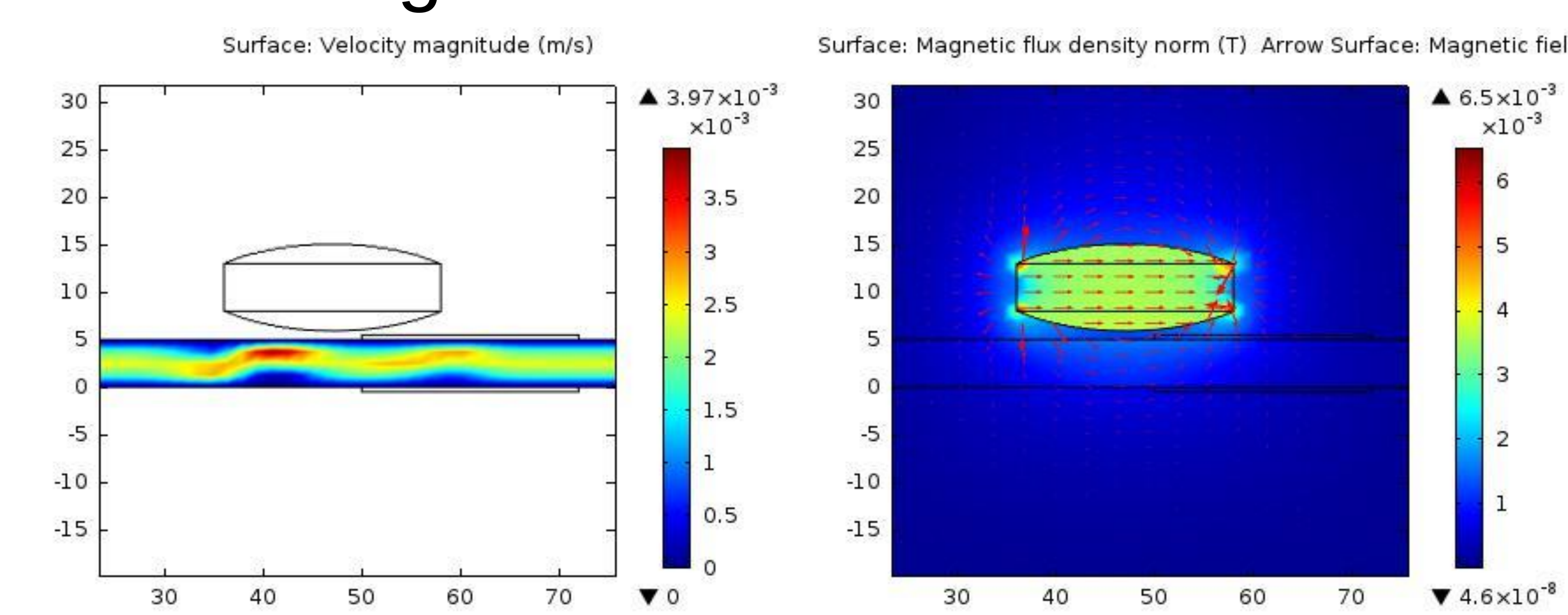

Figure 3. Velocity and Magnetic Field profile from simulation

Ferrofluid near to high temperature area experience less magnetization and fluid at far from substrate experience more magnetization. This cold fluid pushes hot fluid which generates the flow.

Table 1. Output parameters

S.No.	Shape of Magnet	Velocity (mm/sec)	Temperature (K)
1.	Concave	1.532	319
2.	Convex	1.592	321
3.	Tapered	1.986	321
4.	Rev. Tapered	1.956	314
5.	Trapezoidal	1.137	328
6.	Rev. Trapezoidal	1.267	326

References:

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