Experimental Investigation of Ferro fluid Forces under Different Voltage

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Abstract—*Ferro fluids are colloidal suspension of magnetic particles which respond to external magnetic field enabling the possibility of charging the magnetic flux by moving an external magnet about it. In this present study iron powder are first synthesized with water and surfactant in the lab using co-precipitation technique followed by ferrofluid preparation, magnetic properties are characterized. Here ability to produce a fluid phase of magnetic material to demonstrate the generation of energy using a simple set up and this energy is demonstrated to produce useful work. Ferro fluids are successfully synthesize and experimental result shows generation of voltage change between 15-85 volts at critical parameter such as force measurement which has been made and illustrated analytically for different voltage. The counter load sustained ferrofluid of different percentage of ferrous powder and surfactant have been observed by increasing in applied voltage. It has been also observed that increase load is accomplished with increase in ferrous powder concentration.*

Keywords — *Ferro fluids, magnetic materials, critical parameters, force measurement, fluid phase*

I. INTRODUCTION

Ferro fluid is a liquid which becomes strongly magnetized in the presence of magnetic field. There are at least three components required to prepare ferrofluid i.e. magnetic particles of colloidal size, carrier liquid and stabilizer (surfactant). They are stable suspensions of colloidal single domain ferromagnetic particles of the order of 10nm in suitable non-magnetic carrier liquid. If the size of permanently magnetized nano-particles will be less than 1-2 nm, the magnetic properties will disappear and colloidal motion increases with decreasing the size of the particle. The colloidal particles, typically made from magnetite (Fe3O4), are coated with surfactants to avoid their agglomeration under Vander Waals attraction forces and dipole interaction among them. The presence of surfactant helps to maintain proper spacing between the particles to provide colloidal stability. Ferro fluids were first discovered at National Aeronautics and Space Administration (NASA) Research Center in mid 1960‟ s. The scientists at NASA found that they could make to flow this amazing ferrofluid by varying the external magnetic field.[1]A magnetic colloid, also known as a ferrofluid (FF), is a colloidal suspension of single-domain magnetic particles, with typical dimensions of about 10 nm, dispersed in a liquid carrier. The liquid carrier can be polar or non polar .Ferro fluids are different from the usual magneto rheological fluids (MRF) used for dampers, brakes and clutches, formed by micron sized particles dispersed in oil. In MRF the application of a magnetic field causes an enormous increase of the viscosity, so that, for strong enough fields, they may behave like a solid [2].The magnetic control of flow of liquid material is a challenging possibility leading to consequences for hydrodynamics. In general and for application engineering in particular. As it is well known from solid state physics, magnetic materials like iron or cobalt lose their interesting magnetic properties at temperatures far beyond the melting point. Liquid metals and other molecular liquids like. paramagnetic salt solutions require extremely high magnetic fields in the order of several Tesla to enable a magnetic influence on their behaviour .A way out from this problem is the use of colloidal suspensions containing small magnetic particles in appropriate carrier liquids. Stable suspensions of this kind were first synthesized in 1964 by Papell . meanwhile technical importance's have been reached in everyday life. Ferro fluids are optically isotropic but, in the presence of an external magnetic field, exhibit induced birefringence. Wetting of particular substrates can also induce birefringence in thin FF layers [1]. **Williams .A.M** [2008] has been work on the different model of the ferrofluid surface instability. In the first section of their paper, they review recent contributions of Ferro hydrodynamics. In a second section, fluid instabilities involving magnetically-susceptible fluids has been reviewed, including the labyrinthine, normal field, Rayleigh-

Taylor, and Kelvin-Helmholtz instabilities [3]. **Odenbach .S[2003],** has studied about the ferrofluid and showing, that the viscosity of the fluid is strongly influenced by magnetic field and small fraction of large particles in the fluid forms chains dominating the rheological properties of the fluids in the presence of magnetic field. Furthermore it has been found, that the magnetic structures formed do not only lead to a viscosity increase but also to the appearance of magneto viscoelastic effects[4]. **Srnsstn .S.R** in1977 were carried out a number of experiment with a Ferro fluid Density separator to determine the practicality of separating micrometer-size particles in to density fractions .The separators are normally used on much coarser material .The experimentation demonstrated that density separations of nonmagnetic particles as small as 50 micrometer were effective and reproducible and that the separator was easily operable far above the density of conventional liquid separation systems Separations with smaller particle sizes were sometime successful, but they could not be consistently reproduced[5]. **Lemarquand .V et al**,[2008] has proposed the analytical model for evaluation of the static behavior of ferrofluid seal their shape and static capacity as working as a bearings in the magnetic field created by ring permanent magnets[6]. **Tze-Chi Hsu et al[2013]**,objective of their study was to investigate the performance of ferrofluids under the combined influence of surface roughness and a magnetic field generated by a concentric finite wire. The distribution of pressure was obtained and used to calculate the characteristics of the bearing. The results of this study indicate that the combined influence affect the distribution of film pressure, which enhances loading capacity and reduces the modified friction coefficient. The effect of longitudinal roughness was particularly significant and we expect these findings could further enhance the design of short journal bearing within a magnetic field[7], **Papell .S.S**[1968] has first given the description of a laboratory method for preparing magnetic solutions, composed of ferromagnetic sub-micrometer particles as a stable colloidal dispersion in 2-heptane. They prepared the sub-micrometer particle by grinding the ferromagnetic for several weeks mixed with solvent [8]..**Lin .J.R**[2013] has work on ferrofluid squeeze films including the effects of convective inertia forces and the presence of transverse magnetic fields has been derived for engineering application. As an application, the problem of parallel circular disks is illustrated. It is found that the ferrofluid circular squeeze film considering fluid inertia effects provides a higher load capacity and a longer elapsed time as compared to the non-inertia non- ferrofluid [9].. **Zhan .M et al,**[1993] have done experiment on the traveling wave magnetic field without a free surface is to analyzed time average magnetic force and torque and numerically solving the coupled linear and angular momentum conservation equations. They show that, it is necessary that the fluid convection and particle spin terms be significant in the magnetization constitutive law and that spin viscosity be small in order to predict the experimentally observed reverse pumping at low magnetic field strengths and forward pumping at high magnetic field strengths [10]. **Charles.W.S** in [2002]discussed the preparation of particles, ferrofluids and magneto rheological fluids has been the subject of numerous patents and res earch publications[11] **Petit.M et al,** in [2014]working on the electronics devices cooling using the ferrofluid it is general fact that Liquid cooling of electronic devices requires generally a mechanical pump which reduces the performance of the system and its reliability. They use low curie temperature ferrofluid are able to create a liquid flow without any mechanical part. In fact a pressure gradient can be obtained when subjecting this ferrofluid to both a temperature gradient and a magnetic field.. The results confirm that a hydrostatic pressure can be successfully created. A pressure drop is also highlighted and discussed in terms of temperature gradient evolution and magneto-convection in the ferrofluid[12].**Bhat.M.Vet al,** in[2004]works on the different model for a given magnetic field and found that the load capacity and response time are more in the Neuringer Rosensweig model than in the Jenkins model because the material constant in the latter model causes reduction in them. In the Shliomis model the rotational viscosity parameter causes increase in the load capacity and response time only marginally when magnetic field strength is uniform. The effect of magnetization of the fluid particles predominates that of their rotation. A uniform field cannot generate magnetic pressure in the N–R model, but it can affect the bearing characteristics in the Shliomis model owing to the rotational viscosity. The load capacity and squeeze time are more in the case of a non-uniform magnetic field than in the case of a uniform magnetic field owing to the effect of magnetization in the former case [13]. **Kuzhir.p** in[2008]has work on the ferrofluid sealing and proves that behavior of ferrofluid film boundary adjacent to ambient air is crucial for the proper design of the sealing unit of ferrofluid bearings. And try to predict the shape of a ferrofluid free boundary in the presence of a static load and magnetic field. And integrate Reynolds equation and the free boundary equation using perturbation technique with respect to shaft eccentricity [14]. **KOPČANSKÝ .P et al,** in **[2010]** work on the different ferrofluid and their applications. In that he discuss briefly history of magnetic fluids, the role of magnetic particles in magnetic fluids, their basic properties and some technical and biomedical applications. In detail some of the main results of magnetic fluids for power transformers, composite systems of liquid crystal and magnetic particles and magnetic fluid for drug targeting are presented [15]. **Franklin .T.A** in [2003] work on the investigation of ferrofluid and analysis is presented in three parts a characterization of ferrofluid properties, a study of ferrofluid flow in tubing and channel systems, and a study of ferrofluid free surface sheet flow. The characterization of ferrofluid samples is completed through analysis of magnetization curves measured with a vibrating sample magnetometer. Determination is made of the ferrofluid particle size range, saturation magnetization, low-field magnetic permeability, and magnetic volume fraction. A detailed discussion of the demagnetization factor within the ferrofluid sample is also included. Ferrofluid flow through circular tubing in a laminar regime is examined as a function of the applied magnetic field, direction, and frequency. Gradients within the applied magnetic field create a magnetic contribution to the pressure drop across a length of tubing. Experiments of ferrofluid flow through a rectangular channel with a free surface when driven by a rotating spatially uniform magnetic field exhibit an anti-symmetric flow profile across the channel width, with a net zero flow rate . The cause of the decrease in sheet radius is a magnetic field induced decrease in ferrofluid pressure as well as a magnetic field enhanced convective Kelvin-Helmholtz instability. A thorough theoretical development describes the observed phenomena [16]. The main focus of this paper is to study about the ferrofluid, and synthesise of ferrofluid and To obtain the relation between strength and voltage of ferrofluid on different concentration To understand the dynamics of ferrofluid and its potential used for the development of ferrofluid based mechanical applications. In this study firstly ferrofluid have been prepared, for creating enough magnetic field , designed electric circuit with ammeter voltmeter has been made, and after that to check the strength at different voltage & composition mechanical setup has been used and by varying the weight the optimal strength of the composition has been calculated.

II. EXPERIMENTAL PROCEDURE

. For the experiment purpose ferrofluid is required which is synthesise by mixing the ground iron powder at different ratio in water and surfactant. The volumetric ratio of the iron powder, water and surfactant as follow. The product made by LOBAL chemie and the powder made by electrolytic reduction of size of 250-300 mesh It contains min 99.85% Fe and other alloying elements are as Cu,Mn,S,Ni,Pb and Zn. The Surfactant used here are the product of Amway and product name APSA 80^{TM} shown in Fig.1 and its composition are as follows in table no.1

Table no.1: Surfactant composition.

Chemical name	Common name	Weight%
Poly(oxy-1,2-ethanediyl),alpha,-(nonylphenyl)-,omega,-hydroxyl.	Surfactant	60--100
1-Butanol	Alcohol	10-30
Fatty acids, tall-oil	Fatty acid	1-5

Distilled water has been used here for the solvent The distilled water is made by the Hi-tech surfactants are added during the synthesis of ferrofluids to surround the small particles and overcome their attractive tendencies. For this aqueous-based synthesis of ferrofluids using magnetite, Fe_3O_4, the surfactant tetramethylammonium hydroxide, $[N(CH_3)_4][OH]$, is used. The nano particles created by the synthesis are thought to be coated with hydroxide ions from the surfactant, which themselves attract a sheath of largely positive tetramethylammonium cations. This structure creates electrostatic inter particle repulsion that can overcome the Vander Waals forces that would otherwise cause the particles to agglomerate

Fig .1:Iiron metal powder 250-300 mesh size

Fig.2. Distilled water and surfactant

Table -2: Different composition of iron powder, water &surfactant.

%Volume of magnetite	%volume of surfactant	%volume of the water	Total volume in ml
15	10	75	300
20	15	65	300
25	20	55	300

By taking one by one following composition on the jar and mixing proper time about 30 min each in the drilling machine by using the blade on the place of drill bit as shown in figure-3

Fig 3:-Mixing of iron powder water & surfactant

After that the mixture is well stir in the specific design arrangement for 30 minutes. And put the ferrofluid in different sealed and labelled jar. Preparation of the experimental setup in the workshop have been prepared with the two pulleys and stand arrangement as shown in the Fig.4.

Fig 4:- wooden stand

Size of the stand was with following specdification .Base length 25cm,Top length 40cm,Height of stand from bottom to top 45cm,Diameter of two pulley are equal i.e. 5cm each., Width of the base of stand is 10cm.,Width of the top of stands 8cm. Makeing the electrical setup magnetic field was induced and by varying the counter weight at different compositions of ferrofluid and optimal force that the system resist has been found out. Line diagram of experimental set up has been shown in Fig-5

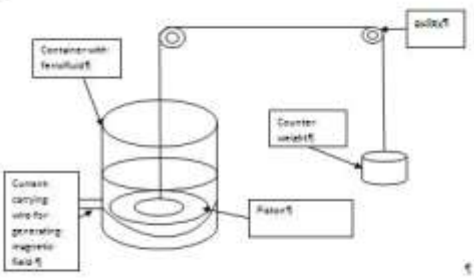

Fig 5.:- line diagram of the experimental set up.

For conducting the experiment, magnetic field is required. Magnetic field is generated by the current carrying solenoid. On the iron pipe which is sealed from one side is used as a beaker, doing copper winding of 1500 turn. The size of copper wire is 23 SWG (standard wire gauge) as shown in Fig.6

Fig 6 .copper winding of current carrying solenoid

When the current flow in the coil a strong magnetic field is created and magnetizations of the ferrofluid take place. In the ferrofluid magnetic particle form a chain and the strength of the system is changed. That strength is measured by the specific designed weight and counter weight arrangement. As shown in Fig.7 By using the different counter weight on the arrangement strength of the ferrofluid is calculated.

Fig .7- electrical setup used for generating magnetic field for different voltage.

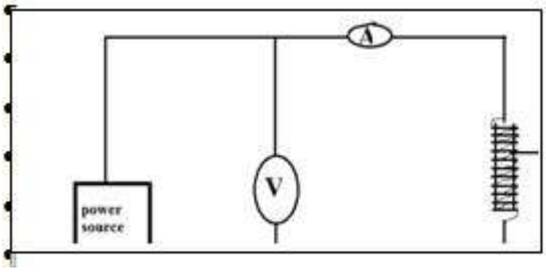

Fig 8:-line diagram for electrical setup

The voltage regulator is used to change the voltage and measure the strength of liquid of various compositions given above . Strength of Ferro fluid is directly prepositional to voltage applied in this voltage regulator Voltage is varying 0-260 volts, but our requirement is only for varying voltage 0-85 volts because the design of our project is only for that voltage withstand.

Fig .9:-A.C Voltage regulator

Fig .10:-experimental set up of voltage and loads

If voltage is increase then loads also increase because strength of magnetic field increase so load caring capacity also increase but after certain voltage magnetisation is over then load are increasing slowly. Voltage and loads are directly prepositional to each other. At the different – different voltage loads carrying capacity was also different but some fixed voltage load has been mentioned below. At the optimum voltage the spice has been formed on the top of the magnetic coil.

III. RESULT &.DISCUSSION.

Experimentally measurement of the ferrofluid forces under different voltage applied in terms of counter weight for different composition of ferrofluid has been shown in table 3.for different voltage, counter weight is measured in terms of gm

Table-3

Voltage (V)	VOLUME PERCENTAGE OF IRON POWDER		
	15%	20%	25%
	Counter weight in gm	Counter weight in gm	Counter weight in gm
15	11.0	14.4	19.0
20	12.5	16.1	25.6
25	13.8	18.5	30.7
30	16.6	22.1	37.9
35	20.1	26.2	48.3
40	25.7	30.3	60.1
45	29.3	36.1	75.3
50	33.3	42.5	89.1
55	37.1	45.3	107.2
60	39.6	48.3	116.4
65	42.4	50.4	123.0
70	43.1	52.1	129.1
75	43.9	53.5	133.2
80	44.5	54.2	138.8
85	44.8	54.9	144.3

In experimental work counter weight was increasing due increasing in voltage. Here three graphs has been plotted between applied voltage and counter weight for different composition of iron powder. For 15% iron powder, 10% surfactant, 75% water the graph is plotted between load and voltage. load on the Y-axis and voltage on X-axis the nature of graph is shown below.in Fig-10

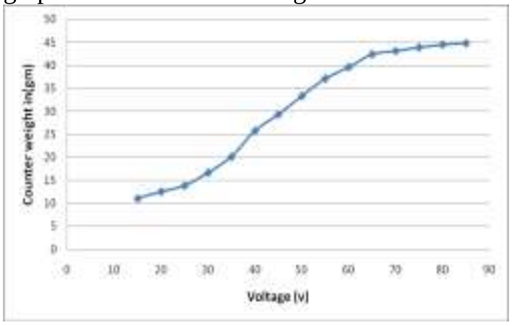

Fig-11, Counter weight in (gm) vs. Voltage (v), if 15% composition of iron powder.

Voltage was varying from 0-85 volt load were increase uniformly up to 30 volt after that, voltage increasing 30-60 volt , load are suddenly increasing due to strong magnetic field created ,after 60-80 volt load are increasing but very slowly due to magnetisation of Ferro fluid. Due to low composition of iron powder small spice size is formed on top of magnetic coil.

Fig.12. spice are formed on the top surface of magnetic coil.

The composition of iron powder increase i.e. 20% iron powder,15% surfactant and 65% of water. The range of voltage is remains same i.e.0-85volt.the load carrying capacity increase as shown in the graph below.

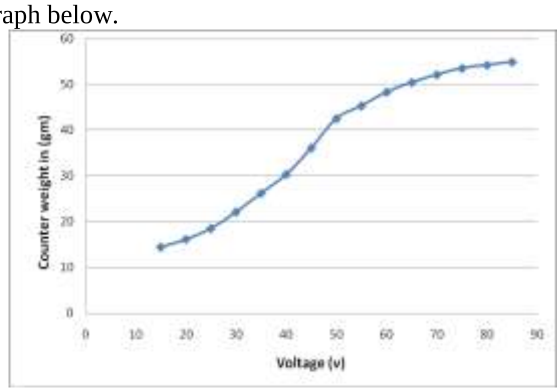

Fig-13. counter weight in (gm) vs. Voltage (v), if 20% composition of iron powder.

Voltage was increase 25-50 volt load carrying capacity suddenly increase after that voltage increase loads also increase but gradually very small amount because fluid was magnetising After certain voltage due to medium composition of iron powder the spice are formed bigger compare to 15% composition of iron powder.as shown in Fig.14.

Fig. 14. Medium size of spice is formed on the top of coil.

The composition of iron powder increase i.e,25% of iron powder,20% surfactant and 55% of water the range of voltage again same i.e,0-85 volt. The load carrying capacity also increasing but slowly for certain range of voltage as shown in graph below in Fig-15.

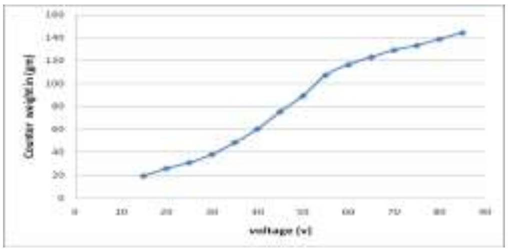

Fig-15., counter weight in (gm) vs. Voltage (v), if 25% composition of iron powder

Voltage was increasing from 35-55 volt load carrying capacity suddenly increasing after that voltage increasing loads increasing very slowly due highest composition of iron powder the bigger size of spice were formed on the top surface of magnetic coil. As shown in Fig-16.

Fig. 16. Bigger size spice is formed on the top surface of coil

Based on the above calculation all the three graph has been drawn in a single charts all the three different types of composition of iron powder i.e. 15%,20% and 25%.and voltage are varying 15-85 volts on X-axis and loads(gm) are on the Y-axis as shown in the below graph. As shown in Fig-17

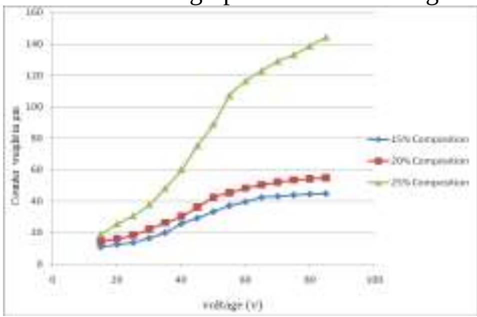

Fig-17, All the three types of composition of ferro fluid and loads (gm) vs. Voltage

From above graph the all three composition of ferro fluid and load acting on the different voltage has been shown. It is clearly indicating that at the higher composition of iron powder the larger load carrying capacity, compare to smaller composition of iron powder.

IV. CONCLUSIONS

This paper has presented an experimental method that the ferrofluid is a magnetic colloidal suspension of single-domain magnetic particles, with typical dimensions of about 10 nm, dispersed in a liquid carrier. The liquid carrier can be polar or nonpolar. For the ferrofluid nanoparticles are synthesise by size reduction and chemical precipitation. And in this experiment by varying the voltage of ferrofluid the optimal strength of ferrofluid can be determined .

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