Effect of magnetic field on Iron Oxide Nanoparticles suspended Magnetorheological fluid and its Viscous Properties

P Sharmili, R Chokkalingam, M Mahendran, S Rahul Gorky, T Santhosh

Abstract*: *Magnetorheological fluid is an admirable class of smart material. This fluid responses and adapts itself to the external magnetic field applied and hence, its rheological properties vary with respect to the field intensity. In this research work, Iron oxide nanoparticles are synthesized by co–precipitation method with ammonia as base reagent. Basic surface and size and magnetic field morphologies of the prepared particles are studied. Synthesized iron particles are used to prepare magnetorheological fluid. The rheological properties of the prepared fluid are studied to know about its viscosity and shearing stress-strain behavior.

Keywords: Magnetorheological fluid, Viscosity, Rheology.

I. INTRODUCTION

Magnetorheology developed as a multidisciplinary field whose significance has extensively expanded these most recent 10 years, since Rabinow and Winslow's disclosures in the 1940s[1]. The rheology of these liquids is extremely attractive since it can be changed by the external field, i.e, either magnetic or electric. The significance of these liquids is their capacity to accomplish a wide range of viscosity in a part of millisecond. With the application of the attractive field, the particles become aligned in continuous chain and arranged along the field of magnetic field. This continuous chain of magnetic particles gets weaken and strengthened based on the external force applied framed. in MR liquids. This gives applications to control vibrations, and applications managing incitation, damping. MR liquids as long as the particles utilized are attractively multidomain and furthermore, display low dimensions of attractive coercivity. The most basic attractive material utilized in arrangement of MR liquids is high virtue iron powder or iron nanoparticle.

MRF has far reaching applications. Optimizing few parameters of the fluid give hands for more efficiency of the fluid towards purpose of applications. Selecting the suspension particles and the base fluid are most prominent work that characterizes the whole fluid. To increase the efficiency of the fluid, researchers work on functionalizing the suspension particles and base fluids with additives, lubricants and polymer-based materials. Soft iron particles are chosen foe easy magnetization and demagnetization. Iron oxides have a place with the richest minerals what's more, happen with an enormous assortment of stoichiometries, structures and properties. Nanosized iron oxide particles inside different arranged mesoporous silicas, Nanosized iron and mixed iron-cobalt oxides are also used as suspension particles[2,3]. Iron particles are functionalized for easy dispersion in the base fluid. Various research on incorporating iron oxide in MRF has been carried out by researchers. Optimization to the particles helps in stabilizing the fluid.

This research involves preparation of Iron oxide nanoparticles in easy method followed by incorporating the prepared nanoparticles to fabricate MRF fluids. The basic morphology for the Iron oxide nanoparticles is studied and the rheological properties for the fabricated MRF is analyzed. The rheological studies include shearing stress-strain behavior, viscosity studies. Sedimentation of the particles is also studied to know the stability of the fluid. Studying the viscosity behavior of the MRF can assist for engineering desired applications of MRF.

II. EXPERIMENTAL PROCEDURE

The coprecipitation method is most likely the least difficult and most effective compound pathway to get attractive Iron oxide particles. The precursors were taken and aqueous ammonia solution was included dropwise with consistent mixing until the pH of the arrangement achieved 10. They were washed a few times with washing agents. The accelerates were dried in oven at 70∘C for 24hrs. The particles were characterized by X-ray diffraction (XRD), using the Debye-Scherrer equation. The obtained micrographs were then examined for particle size and shape. The magnetic property of the solid was measured at 300K using a Vibrating sample Magnetometer. Later, the synthesized iron particles are dispersed in the considered quantity of mineral oil with paraffin as high content (Thermo Fisher Scientific)

which is preferred base fluid of MRF. MRF samples S1, S2, S3, S4, S5 with 75%, 60%, 45%, 80%, 50% of particle concentration are prepared by varying the composition of the contents in MRF.

Revised Manuscript Received on December 09, 2019.

* Correspondence Author

P Sharmili, Department of Physics, Kalasalingam Academy of Research and Education, Krishnankoil, Tamil Nadu, India. Email: sharmilipandian.s@gmail.com

R Chokkalingam*, Department of Physics, Kalasalingam Academy of Research and Education, Krishnankoil, Tamil Nadu, India. Email: chokka84@gmail.com

M Mahendran, Department of Physics, Thiagarajar College of Engineering, Madurai, Tamil Nadu, India. Email: manickam-mahendran@tce.edu

S Rahul Gorky, Department of Physics, Kalasalingam Academy of Research and Education, Krishnankoil, Tamil Nadu, India. Email: rahulgorkys97@gmail.com

T Santhosh, Department of Physics, Kalasalingam Academy of Research and Education, Krishnankoil, Tamil Nadu, India. Email: santhosh.daniel222@rediffmail.com

Further the rheology behavior of the fluid is measured with Anton Paar rheometer.

III. RESULTS AND DISCUSSIONS:

A. Structural Studies:

Fig 1 shows X-beam diffraction of prepared Iron oxide. In the XRD pattern obtained, the peaks are seen due to Fe2O3 and no peak is identified because of some other material or stage showing a high degree of virtue of the as-combined example. The broadened in diffraction peaks are owing to variation in the crystallite size [4]. The expanding of the X-beam diffraction lines, as found in the figure, reflects the nanoparticle idea of the synthesized sample. In X-beam diffraction, some unmistakable pinnacles were considered and relating d-values were contrasted and the standard record JCPDS file no. 85-0987 [2]. Sharpness in the peak indicates crystalline development of the oxide particles.

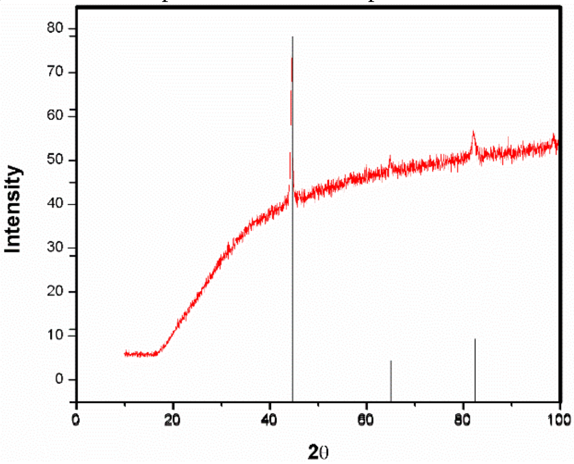
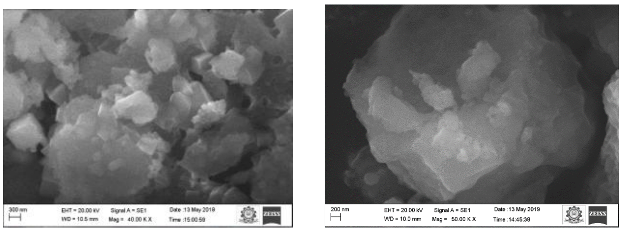


Fig 1: XRD pattern for Iron oxide particles

Fig 1 shows X-beam diffraction of prepared Iron oxide. In the XRD pattern obtained, the peaks are seen due to Fe2O3 and no peak is identified because of some other material or stage showing a high degree of virtue of the as-combined example. The broadened in diffraction peaks are owing to variation in the crystallite size [4]. The expanding of the X-beam diffraction lines, as found in the figure, reflects the nanoparticle idea of the synthesized sample. In X-beam diffraction, some unmistakable pinnacles were considered and relating d-values were contrasted and the standard record JCPDS file no. 85-0987 [2]. Sharpness in the peak indicates crystalline development of the oxide particles.

B. SEM

Fig 2 (a) and 2 (b) shows the particle sizes and morphologies of iron oxide nanoparticles obtained by co precipitation method. Comparing image (a) and (b) it is clear that (b) shows less agglomeration in particles than (a). Analysed SEM results shows that the prepared particles are irregular in shape. The nanoparticles are agglomerated and the size of the particles observed ranges between 200-300 nm from the data shown in fig 2.



(a) (b)

Fig 2: SEM micrograph of Iron Oxide

C. Magnetic studies

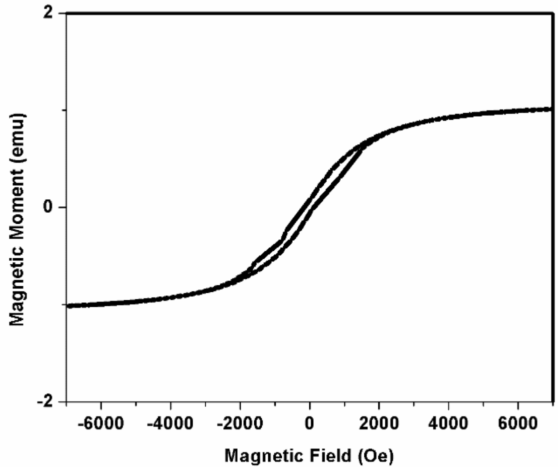


Fig 3: VSM measurements for Iron oxide

The magnetic measurements for iron oxide particles was completed at room temperature and the obtained data was given in fig 3. This estimation of attractive moment backings the certainty that the blended iron oxide is as Fe2O3 with genuine magnetic moment 5.92 B.M [2]. This demonstrates the nearness of 5 unpaired electrons in Fe2O3. Attractive estimations were likewise completed at temperatures extending from 300K to 100K to decide the temperature of Morin transition.

Saturation magnetization, M_s, calculated from extrapolation of the plot of M vs. 1/H. VSM contemplates were done at 300K to demonstrate hysteresis conduct of nanosized particles and it has been observed.

D. Rheology:

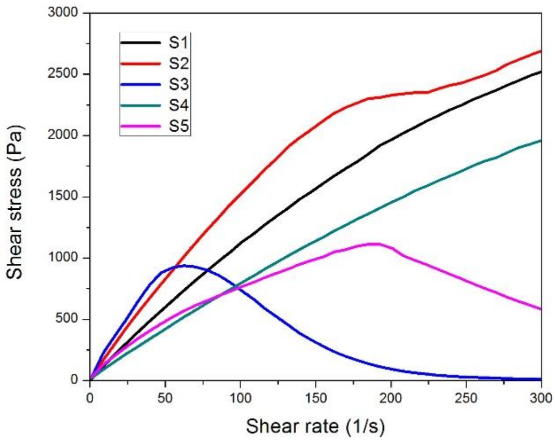


Fig. 4: Flow curve data for synthesized MRF samples

Retrieval Number: B12041292S219/2019©BEIESP
DOI: 10.35940/ijitee.B1204.1292S219

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Fig 4 shows the shear stress and shear rate parameters for the synthesized MR fluids. Shear stress is analyzed with shear rate as a varying function. Magnetic field is produced with help of electromagnetic coil. In this analysis applied field is maintained stable at 0.5T. Yield stress of the sample is a significant factor which determines the stress resistance of the fluid. According to the data obtained it can be known that shear stress increases with shear rate applied. For sample S3 and S5 breakdown in flow appears earlier than other samples. Sample S3 has only low composition of suspended particles compared to the ratio of base fluid. The breakdown of interlinking in particles occurs due the low yield stress of the fluid. Samples with 60% and more in particle concentration has good yield stress due to high ratio of particles concentration in the fluid

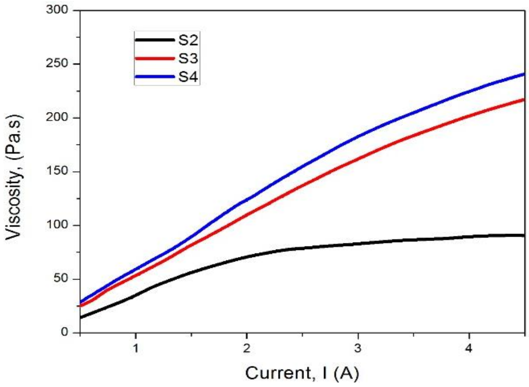


Fig 5: Viscosity curve for prepared MRF samples

Fig 5 shows the viscosity behavior of the MRF samples. Here, viscosity varies with applied field as function factor. Shear rate is maintained stable at ranging about 300s-1. MRF shows Newtonian behavior in the absence of magnetic field and non-Newtonian behavior in the presence of magnetic field. From fig 5 it is clear that viscosity of MRF increases with increase in the magnetic field. Sample S3 and S4 has stable performance than sample S2. The high viscosity of the sample hands up for efficient automobile application.

E. Sedimentation:

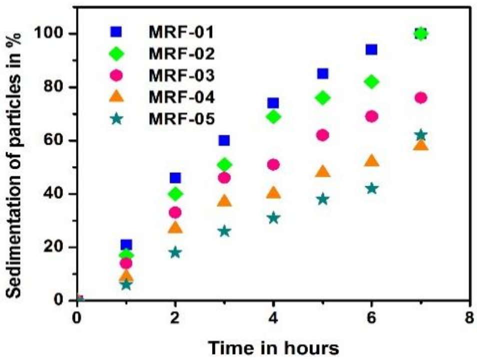


Fig 6: Sedimentation ratio of the synthesized MRF samples

Sedimentation studies of MRF shows the stability of MR liquid. This stability of the samples relies upon the substance of iron particles and the kind of the oil preferred. Sedimentation is one of the undesired properties of MRF which lows its efficiency, life time and the usage. The sedimentation was estimated by visual perception of the position changes of limit among clear and turbid part of base oil [5]. Fabricated samples were put into round and hollow glass test tubes for 7 hours. Accordingly, sedimentation proportion was determined.

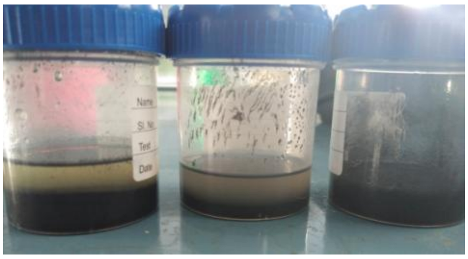


Fig 7: Sedimentation of particles seen in the MR Fluid

IV. CONCLUSION

The Structure of the prepared Nano particles were confirmed by XRD as rhombohedral structured. Magnetic studies reveal ferromagnetic nature of the Iron oxide particle. SEM images confirm the particle size and it is found to be 200 nm. Viscosity of the fluid is greatly increased and sedimentation of particle over the base fluid is minimized.

REFERENCES

1. Seval Genc¸ and Pradeep P Phul´e, "Rheological properties of magnetorheological fluids", Smart Mater. Struct., vol. 11, pp 140–146, 2002.
2. Avnish Kumar Arora, Mohan Sharma, Ritu Kumari, Vivek Sheel Jaswal, and Pankaj Kumar, "Synthesis, Characterization, and Magnetic Studies of α-Fe2O3 Nanoparticles, J. Nanotech, Vol. 474909, 7 pages, 2014.
3. R V Upadhyay, Zarana Laherisheth and Kruti Shah, "Rheological properties of soft magnetic flake shaped iron particle based magnetorheological fluid in dynamic mode", Smart Mater. Struct., vol. 23, 015002, 2014.
4. H. Asnaashari Eivari A. Rahdar, H.Arabi, Preparation of Super Paramagnetic Iron Oxide Nanoparticles and Investigation their Magnetic Properties, Int. J. Sci. Eng. Invest, vol. 1(3), 2012.
5. Bhau K. Kumbhar, Satyajit R. Patil, Suresh M. Sawant, "Synthesis and characterization of magneto-rheological (MR) fluids for MR brake application", Engineering Science and Technology, an International Journal (2015), pp 1-7, 2015.
6. C. S. S. R. Kumar and F.Mohammad, "Magnetic nanomaterials for hyperthermia-based therapy and controlled drug delivery," Advanced Drug Delivery Reviews, vol. 63, no. 9, pp. 789–808, 2011.
7. B.G. Shetty, S.S. Prasad, "Rheological properties of a honge oil-based magnetorheological fluid used as carrier liquid", Def. Sci. J. 61 (2011) 583e589.

AUTHORS PROFILE

Sharmili Pandian, received her Bachelor degree and Master Degree in Physics. Now pursuing her Doctorate in field of Magnetorheological Fluid.

Dr. R. Chokkalingam, is an Associate Professor. He received his Doctorate in Physics in field of Actuators Applications with Shape Memory Alloys.

Dr. M. Mahendran, earned his Ph.D. from the Madurai Kamaraj University, Madurai in Physics with a focus on ferromagnetic systems. I did my post doc at MIT, USA under the auspicious guidance of Dr. Robert C. O'Handley (Bob). My visit to MIT was sponsored by the DST. I am heading the 'Nano Enabled Smart Materials (NESaM)' Research Laboratory in TCE