A SIMPLE METHOD FOR THE DETERMINATION OF MAGNETO RHEOLOGICAL PROPERTIES OF NANOPARTICULATED COBALT FERRITE BASED MAGNETORHELOGICAL FLUIDS

M. VENKATESWARLU , B. RAJINI KANTH

Abstract: Magnetorheological(MR) Fluids are a class of smart materials whose rheological properties rapidly varied by applying a magnetic field. These are the suspensions of soft magnetic particles in a carrier fluid. The suspended magnetic particles interact to form a structure that resist shear deformation or flow of the fluid. This change in the material appears as a rapid increase in apparent viscosity. These smart systems and structures would benefit from the change in the viscosity or other material properties of MR fluids. The applications of these MR fluids include brakes, dampers, clutches and shock absorbers systems. In this line, cobalt ferrite ($CoFe_2O_4$), nanoparticles have been synthesized by a simple wet chemical method. These ferrite nanoparticles fired at temperature 800°C, for 6 h. The composition, phase, and morphology of the prepared ferrite were determined by energy dispersive X-ray analysis, X-ray diffraction, scanning electron microscopy, respectively. The average particle size for these samples was found to be 500 nm. The viscosity of the cobalt ferrites based MR fluids (PVP as the carrier fluid) at room temperature were investigated using a simple capillary viscometer and in house equipment at different low fields (0-150 G). These MR properties were compared (without magnetic field and at different magnetic field strengths) and presented in this paper.

Keywords: Cobalt ferrite nanoparticles, Magneto Rheological Properties, Damping.

Introduction: Magnetorheological (MR) fluids are a class of smart materials whose rheological properties (e.g. viscosity) may be rapidly varied by an applied magnetic field [1-3]. In the presence of magnetic field the suspended magnetic particles interact to form a structure that resists shear deformation or flow. This change in the materials appears as a rapid increase in apparent viscosity or in the development of a semisolid state [4, 5]. The stronger the field the greater the effect on the properties of the MR fluids such as viscosity [6]. MR fluids are not affected by minor chemical impurities, therefore less restrictive and cheaper manufacturing processes may be employed. MR fluids are non-toxic, environmentally safe and compatible with most other materials employed in automotive manufacturing. Study of these magneto-rheological fluids derives from their ability to provide simple, quiet, rapid-response interfaces between electronic controls and mechanical systems [7]. MR fluid devices are being used and developed for shock absorbers, clutches, brakes, and seismic dampers [3, 5]. But characterizing these fluids sophisticated instruments are need and which were costly and not many available, so we have made an attempt to measure its viscosity under magnetic field using simple capillary method.

Keeping the above points in view we have synthesized and characterized nanosized cobalt ferrite particles with 30 wt% of PVP solution to know the effect of magnetic field on the viscosity of the MR fluid using a simple capillary method. We have also presenting the study of their dynamic MR behaviour with different field levels, to know how fast the present samples respond to the field and their damping behavior and details were presented in this paper.

Synthesis and characterization of cobalt ferrite nanoparticles

Pure chemicals (99.9%) of iron sulphate, cobalt sulpahte and NaOH were taken and in three separate beakers. The solutions of $FeSO_4$ $7H_2O$, and $CoSO_47H_2O$ and NaOH were made. After heating the iron and cobalt sulphate solutions to 75 ºC and mixing the two solutions while stirring with a stirring rod. The solution was then heated to 90 ºC for 10 min while stirring. After getting the perfect mixture, NaOH solution was added to the mixture drop by drop. After reaching a PH of 10, a green suspension was formed and rapidly turned to black. The black suspension was cooled to room temperature. The precipitate was filtered with a Büchner funnel. The black solid was washed several times with distilled water while in the funnel. The filter paper was pulled out of the funnel and placed it on a watch glass, and dried it in an oven at 100 ºC. The black powder was scrapped off of the filter paper. The collected powder was heat treated at around 800 ^{o}C in a ceramic boat for six hours.

Fig. 1 shows the XRD pattern of the cobalt ferrite sample powder. All the peaks were found to be sufficiently intense. These peaks were marked from the standard data and they match well with the present data. From this X-ray density and porosity were calculated.

Fig.2 shows the SEM photograph of the cobalt ferrite powder sample. The sample was found to be fine grained and having the average grain size of 500 nm.

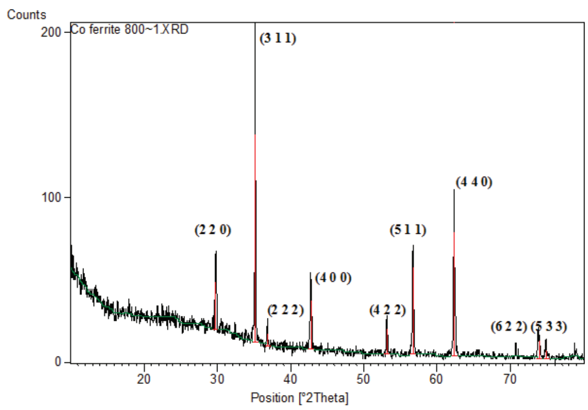


Fig.1. XRD pattern of Cobalt ferrite powder

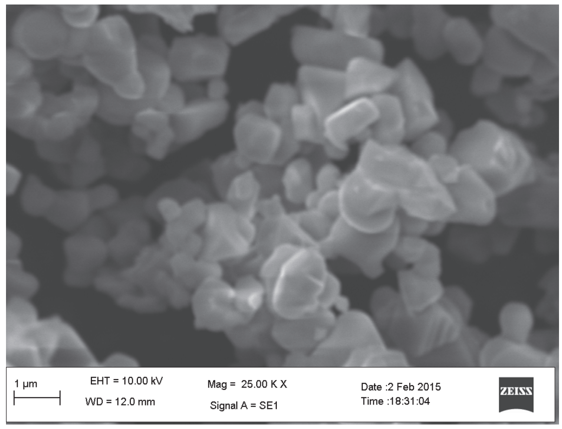


Fig.2. SEM data on Cobalt ferrite

Preparation of MR fluids and MR characterization using capillary method

Cobalt ferrite, was mixed with 30 wt% weight percent solution of PVP to make the Magneto Rheological fluid samples. The MR samples were stirred using a homogenizer for half an hour with an average RPM of 2000. These samples were characterized using simple capillary method the field was varied by controlling the current in the coil made of 300 turns (30 SWG). The coil was calibrated using the Polytronics (PVT LTD) axial hall probe. The current in the coil was controlled by changing the resistance connected in series to the coil.

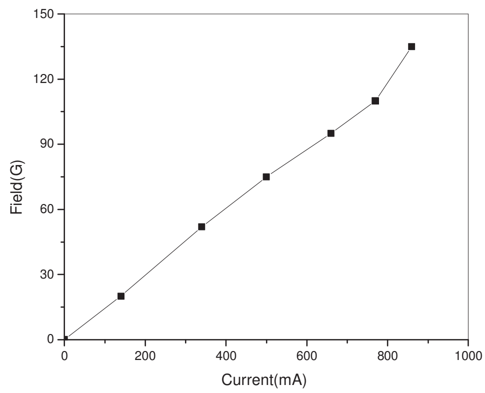


Fig.3. Current vs field (Coil electromagnet calibration curve)

The coil was calibrated using the axial hall probe. Fig. 3 shows the calibration curve. The field increases linearly with the applied current. The current is varied from 0 to 900 mA and the field changed from 0 G to 145 G. The viscosity of the MR fluid was determined by an indirect method, using water and PVP solutions as the reference fluids of the known properties. A formula derived by Poiseuille[8] was used for this purpose[9]. By using the capillary tube without and with magnetic field. The viscosity was calculated in line with the Ref.[10]. The Coefficient of viscosity was given by the equation,

$$\eta = \frac{\rho t}{\rho_g t_g} \eta_g$$

Where

ρ----- density of the magneto rheological fluid,

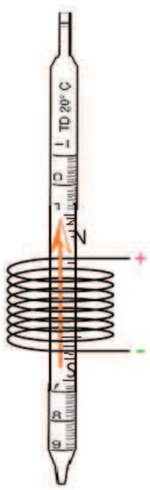
t------ out flow time of the magneto rheological fluid from the capillary,

ρ_g ---- density of the reference fluid,

t_g----- out flow time of the reference fluid from the capillary,

η_g----- viscosity coefficient of the reference fluid.

The Schematic diagram of the present experimemt is as shown in the following figure.



4.

Fig.4 shows the experimental arrangement

Fig. 5 shows the viscosity variation without and with the field. As the field increases from 40 G the viscosity also slowly increases and after the field reached 110 G there is a sudden variation in the viscosity. This is due to magnetic particles aligning to the field direction and forming like a chain and abstruct the flow of the fluid. The time was measured with a stop watch with an accuracy of 0.2 s. Further study of the viscosity of the sample is underway in higher field and with different carrier fluids.

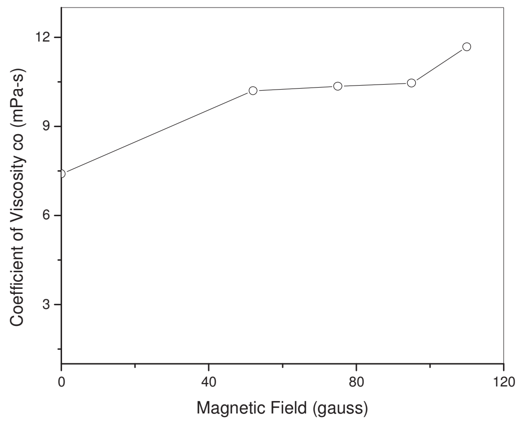


Fig.5. variation of viscosity for the cobalt based MR fluid without and with filed

Conclusions : We have made cobalt based MR fluid and studied its viscosity behavior without and with field using a simple capillary method using the laboratory available equipment and handmade magnetic coils and found that the viscosity of the fluid increases with the field from 0 G to 110 G.

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