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Magneto Rheological properties of Cobalt ferrite based MR fluids

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A B S T R A C T

Magneto Rheological fluids are made of soft magnetic particles dispersed in a carrier fluid. Here cobalt ferrite based magneto rheological fluids were made from the nanopowders of cobalt ferrite obtained from the simple wet chemical synthesis from the metal salts dispersed in the Polyvinyl Pyrrolidone (PVP). The nanoparticle Cobalt ferrite was heat treated at 600C for five and half hours in a furnace. The sample was characterized by using X- ray Diffraction(XRD), Scanning Electron Microscopy(SEM) and Energy Dispersive X-ray Analysis (EDAX). Cobalt ferrite which is mixed with different weight percent solutions of PVP to make the Magneto Rheological fluid samples. These samples were characterized by the Rheometere in both oscillatory, rotational measurement conditions. The variation in viscosity with respect to the magnetic field, storage and loss modulus and damping of the samples were measured and presented in this paper.

Introduction:

Magneto rheological (MR) fluids are dispersions of fine magnetically soft, multi domain particles. MR fluids exhibit rapid, reversible and significant changes in their viscosity and shear modulus when subjected to external magnetic field. The apparent yield strength of these fluids can be changed significantly within milliseconds by the application of an external magnetic field [1-3]. MR fluid devices are being used and developed for shock absorbers, clutches, brakes, and seismic dampers[4].The physical properties of an MR fluid change as a nonlinearly time varying function of applied field driven particle alignment with the typical hysteresis of magnetic materials [5]. The external magnetic field applied to the MR fluid causes changes in all physical properties of the fluid, such as Electrical conductivity, thermal conductivity, permeability, as well as viscosity[3, 6-8].MR fluid viscosity is very much sensitive to changes on external magnetic fields. Viscosity depends on particle concentration, particle shape, size and material in combination with several carrier fluids [5]. In the current MR devices control of the viscosity is performed by the direct excitation of the external magnetic field. The non-linear, hysteretic time varying response of the fluid is an obstacle to precision viscosity control despite fast response time.

Most of the times the MR fluids encounter different operating conditions in which their visco elastic properties plays a vital role. Therefore an understanding of the dynamic behavior of the MR fluid will be crucial for the design[9]. Most of the MR devices operate under dynamic conditions (vibrators, dampers, etc) thus small amplitude oscillatory and rotational measuring rheometer provide more useful results [10]. Keeping these points in view, in the present study we have made an MR fluid which is comprising of magnetically soft Co ferrite nano powders weight percent solutions of PVP and studied their oscillational and rotational viscoelastic properties and results are presented in this paper.

Experimental:

Pure chemicals (99.9%) of iron sulphate, cobalt sulphate and NaOH were taken and in three separate beakers, solutions of $FeSO_4 \cdot 7H_2O$, and $CoSO_4 7H_2O$ and NaOH were also made. After heating the Fe and Co sulphate solutions to 75 ºC and mixing the two solutions while stirring with a stirring rod. After getting the perfect mixture, NaOH solution was added to the mixture drop by drop. After reaching a PH of 10, a green suspension will form and rapidly turn to black. After that heat the solution to 90 ºC for 10 min while stirring. Cool the black

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suspension to room temperature. Filter the precipitate with a Büchner funnel. Wash the black solid twice with 50 mL of water while in the funnel. Pull the filter paper out of the funnel, place it on a watch glass, and dry it in an oven at 100 ºC or on a hotplate. Scrape the black powder off of the filter paper. The collected powder was heat treated at around 600C for five and half hours. Then the sample powder was characterized by XRD, SEM and EDAX. The MR properties (both rotational and oscillational modes) were measured using Anton Paar Rheometer at room temperature in the field of 1mT to 1T.

Results and Discussion:

Fig.1 shows the XRD pattern of the present Cobalt ferrite sample. It shows all the possible peaks, we have compared this data with the literature and the structure of the ferrite matches well with the literature. Fig.2. shows the SEM microstructure of the present sample. From the figure it can be concluded that the ferrite posses fine grain and uniform microstructure. The EDAX plot is shown in the Fig.3 and the data is also the same with the aim with which we have started in the synthesis of this sample.

After ensuring the cobalt ferrite sample formation we have made the MR fluids with the 10, 20 and 30 weight percent solutions of PVP with the appropriate amount of ferrite composition and the samples are designated as sample No.1, 2, 3 respectively. Fig.4 shows the Anton PAAR Magneto Rheometer with which present samples MR properties are studied. Fig.5 shows the variation of viscosity of the present samples with the variation of Magnetic field from 1mT to 1T. As the samples are ferromagnetic at room temperature, the viscosity is slowly picked up for the sample1. From 100mT to 1T it has raised slowly to reach a maximum viscosity. In the case of sample. No.s 2, 3, the viscosity raise started early in between 1mT to 100mT and reached to a maximum viscosity and saturated. This is because of the fact that the sample amount is less in the sample.No.1 and it is more in the case of sample No.s 2 and 3, similarly the sample.1 is less viscous compared to sample No.2 and 3. Sample No.3 has highest viscosity compared to other samples, hence, sample No.3 was selected for further study.

Fig.6. shows the storage modulus, loss modulus and complex viscosity behavior of the sample No.3 with the applied field variation from 1mT to 1T. The storage modulus is slightly positive at the initial stage of the curve and raises from 1mT to 10mT and raises after the field reached to 100mT and when the field reaching towards 1T the storage modulus decreases and the variation in the viscosity was only 1 mPa, where as the loss modulus is initially started with a negative value and raised and made a small peak where storage modulus had a drop and then decreased afterwards and near 1T its value is slightly positive and the complex viscosity rapidly increased and had a peak around the storage modulus had a peak in the field between 100 mT to 1T and decreased afterwards similar to the storage modulus curve.

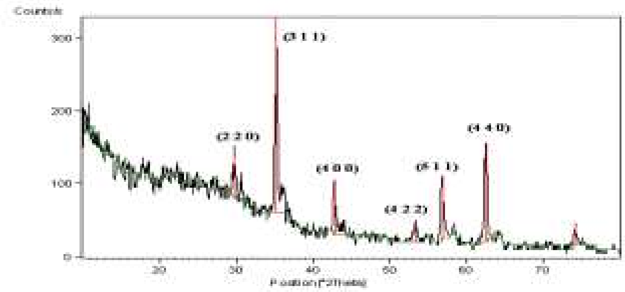

Fig.1.

Fig.2.

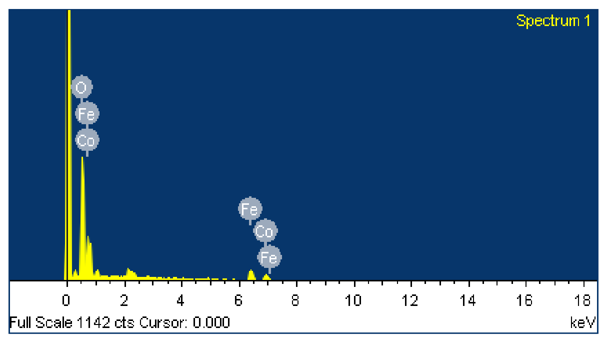

Fig .3

Fig.4.

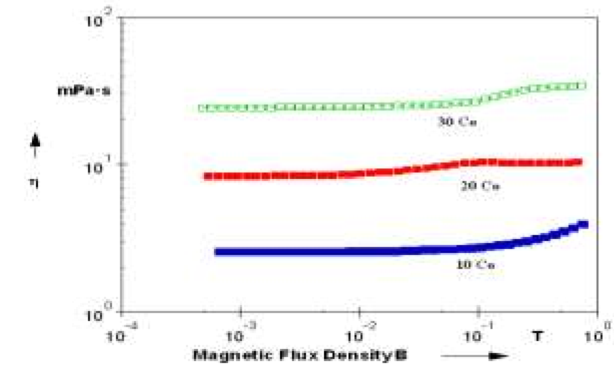

Fig.5.

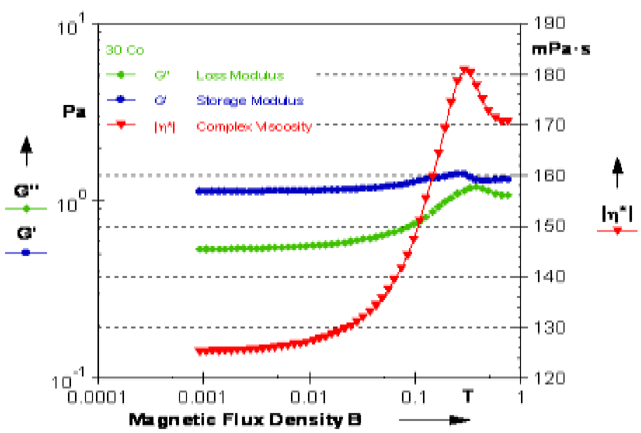

Fig.6.

Conclusions:

Here cobalt ferrite based magneto rheological fluids were made from the nanopowders of cobalt ferrite dispersed in the Polyvinyl Pyrrolidone (PVP). The nanoparticle Cobalt ferrite was heat treated at 600C for five and half hours in a furnace. The sample was characterized by using XRD SEM and EDAX. Cobalt ferrite which is mixed with different weight percent solutions of PVP to make the Magneto Rheological fluid samples. These samples were characterized by the Rheometer in both oscillatory, rotational measurement conditions. The variation in viscocity with respect to the magnetic field, storage and loss modulus and damping of the samples were measured.

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