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Effect of Iron Particles Concentration and Additives on Properties of Magneto Rheological Fluids

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Abstract

Objectives: In this study the methodology of preparation of Magneto Rheological (MR) Fluids is discussed. A comparison of different MR Fluid samples with different concentration of Fe particles and silicon oil is presented. **Methods/Statistical Analysis**: Magneto Rheological (MR) Fluids when suspended to magnetic field change their physical properties. These physical properties can be enhanced by modifying composition of MR Fluid. In this study, the effect of iron (Fe) particle concentration and different additives in Magneto Rheological (MR) Fluids are discussed. In experiment silicon oil, iron particles and additive are used to make MR Fluid. **Findings:** Sedimentation analysis of different samples of MR Fluid was done. It can be concluded that different additives enhance the physical properties of MR Fluid and change in Fe particle concentration effect stability of MR Fluid. **Application/Improvements:** MR Fluids can be used for mechanical as well as biomedical purposes.

Keywords: Additives, Magneto Rheological (MR), Sedimentation

1. Introduction

Nowadays engineers throughout the world are using those materials whose properties can be altered in controlled manner, these kinds of materials are called as Smart materials. Magnetic fluids are also a kind of smart materials. Magnetic fluids change their rheological properties when exerted to external magnetic field. The Magnetic Functional fluids (MF) and Magneto Rheological Fluids (MRF) are the two common types of magnetic fluid. These are differentiated on the bases of inner particle size. The particle size of magnetic functional fluid are about 10 nm but the particle size in Magneto Rheological Fluid are in the order of microns[1].

MR Fluid is a suspension of micro-size magnetically soft particles such as Carbonyl Iron (CI) in a carrier liquid which is magnetically neutral such as silicon oil[2]. MR Fluid in normal condition is a free flowing liquid whose consistency is similar to motor oil. The carrier fluids in which magnetically soft particles are randomly disperse exhibits Newtonian behaviour[3].

Under the influence of applied magnetic field the physical properties of Magneto Rheological Fluid such as rheological, viscosity, permeability, as well as thermal conductivity can be changed[4]. The magnetically soft particles align them self in the direction of magnetic flux forming a chain like structure on aliening particles resist the motion of fluid up to a certain level of shear stress. When this shear stress exceeds some critical value the chain like structure of particles breakdown and flow of material starts. The critical shear stress value at which flow of material starts is called as "apparent yield stress" of the flowing material[5]. The changes in physical properties of MR Fluid are reversible and are dependent upon the applied magnetic field.

Due to adjustable physical properties such as viscosity and fast response time, MR Fluid are used in various applications, based on different modes of operation MR Fluids are widely used in shock absorbers, brakes, clutches, engine mounts, alternators, control valves, vibration damping, optical finishing, sealing systems, in Medical applications for treatment of cancer called tar-

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geted magnetic hyperthermia. Main focus of this paper is to predict the best method for the composition of MR Fluid, which can improve performance and satiability of Magneto Rheological Fluids.

1.1 Composition of MR Fluid

MR Fluids are composed of three basic components.

- Base fluid or Carrier fluid,
- Magnetic soft particles or metal particles,
- Additives.

1.1.1 Carrier Fluid or Base Fluid

As shown in Figure 1 the base fluid work as carrier for metal particles, base fluid should be magnetically neutral. In base fluid metal particles are randomly suspended so it should depicts natural lubricating as well as damping features. The viscosity of base fluid should be low and should be independent of temperature[6]. From the literature review, generally used carrier fluids are silicon oil[1-3] hydrocarbon oil[7] mineral oil or other suitable organic liquids[8].

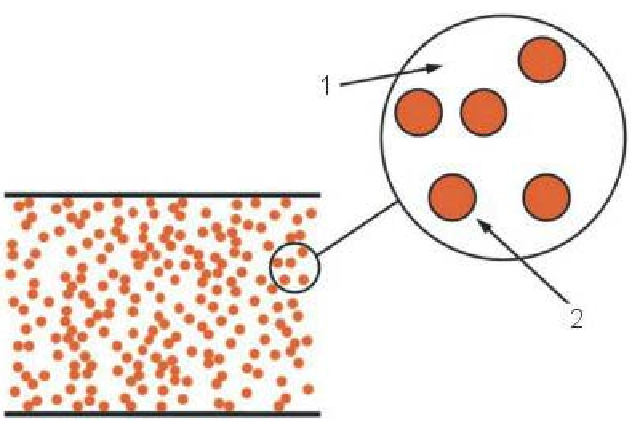

Figure 1. MR Fluid in free flow or no magnetic field condition (1 - Carrier fluid, 2- Randomly suspended magnet soft particles[8].

1.1.2 Magnetically Soft Particles or Metal Particles

General size of metal particles is (~.05 μm -10 μm)[1]. Metal powder should have high saturation magnetization i.e. on removal of external magnetic field these particles should demagnetise and remain dispersed in the carrier liquid. From the literature review, generally used metal particles are iron (Fe) powder[9-10]. Fe_3O_4 with saturation magnetization of 421.3 G [10], Carbonyl iron (CI) with saturation magnetization of 2.1T[11]. Carbonyl iron is generally proffered because; CI particles are low coercivity and have high saturation magnetization.

1.1.3 Additives

Additives are added to MR Fluid to increase its stability and other rheological properties, from different additives used in composition of MR Fluids are GreeceStearic[3] acid to improve sedimentation stability[11]. Iron-Cobalt alloys in the ratio of (90:10), Iron nickel alloys (99:1) increases yield stress of MR Fluid[12] to improve tribological performance of MR Fluid Zinc-dithiophosphate (Zn-DTP) is added to MR fluid to prevent wear, Molybdenum-dithiocarbamate (Mo-DTC) is added to reduce friction, Amine anti-oxidant is added to prevent the oxidation of CI particles when MR Fluid come in contact with air, oxygen present in air reacts with CI particles and oxidise it[8].

2. Methods for Preparation of MR Fluid

From the literature survey it can be concluded that there are two methods, which can be used for the composition of MR Fluids.

- Volume Percentage method[10–12].
- Weight percentage method[1–4,13].

In volume percentage the MR Fluid components; base fluid, metal particles and additives are added on the bases of volume fraction. Whereas on the other hand in weight percentage components of MR fluid are mixes on the bases of weight ratio. After mixing all components in desired proportion the composition is mixed vigorously to ensure the proper mixing of metal particles and additives in carrier fluid, properly mixing of all components will enhance the sedimentation stability of the produced fluid. The rheological properties of MR Fluid depend upon size of metal particle, density of particle, properties of base fluid such as viscosity, intensity and direction of applied magnetic field, temperature and other factors.

3. Preparation and Characterisation of MR Fluid

MR Fluid is a combination of three main components, the continuous phase i.e. Carrier fluid, the dispersed phase i.e. magnetisable particles and additives[2] for preparation of MR Fluid materials used are silicon oil as carrier fluid, silicon oil is used because it exhibits Newtonian behaviour and is anticorrosion, Fe particles as magnetisable particles and automobile grease as additive to reduce sedimentation. For preparation of MR Fluid weight percentage method was adopted. Figure 2 shows the response of applied magnet on MR Fluid. The viscosity of silicon oil is 350 cst at 25°C and from the literature survey magnetically soft particle of 300 mesh size are used. Now all these composites (silicon oil, Fe particles and grease) are mixed vigorously with the help of an electric stirrer with 15000 rpm after stirring we get black colour MR Fluid. As shown in Table 1 now we are checking whether the MR Fluid is effective or not with the help of strong permanent magnet. Prepared MR Fluid is taken in a beaker; a strong permanent magnet is placed parallel to the beaker and is moved in upward direction. With the moment of permanent magnet MR fluid also moves in upward direction as shown in Figure 2 hence, it can be stated that the MR Fluid so prepared reacts to the applied magnetic field.

Figure 2. Response of MR Fluid to the applied magnet.

4. Sedimentation Analysis of the Magneto Rheological Fluid

$$SR = \frac{H_s}{H_T} \times 100\%$$

Sedimentation refers to settling down of particles suspended in fluid under the influence of forces action on them i.e. forces like gravity, centrifugal acceleration and electromagnetism. Here sedimentation ratio (S_R) is defined as the ratio of height of the supernatant oil (H_S) to the total height (H_T) of MR Fluid in the tube.

This set up contains a test tube is held vertically and a ruler is placed fixed adjacent to the test tube to measure the height of supernatant fluid.

The height of supernatant fluid (Hs) is measured after an interval of time. With passage of time, the height of supernatant fluid (Hs) increases and the height of turbid part decreases and hence is measured visually with the help of measuring ruler.

5. Method to Check the Viscosity of Prepared MR Fluid

Figure 3 shows viscosity of MR fluid can be measure by capillary tube viscometer[10].

The fundamental Equation of this capillary tube viscometer is given as:

$$\eta = \frac{\pi r^4 \ \text{tmgh}}{8V^2 \ \text{L}},$$

Where η = viscosity.
r = radius of the capillary tube.
t = measuring time.
h = total height of MR Fluid or height difference between outlet of tube and upper surface of MR Fluid in container.
V = volume of MR Fluid during time t.
m = mass of MR Fluid during time t.
L = capillary tube length.
g = gravity acceleration.

Table 1. Different constituents used and there wt% with respect to (WRT) whole fluid weight

Feparticles (gm)	VegetableOil (gm)	Grease (gm)	Total weight (gm)	Wt% Of different materials WRT whole fluid weight		
				Fe Particle	silicon Oil	Grease
38.91	22.35	1.75	63.048	61.71	35.45	2.77

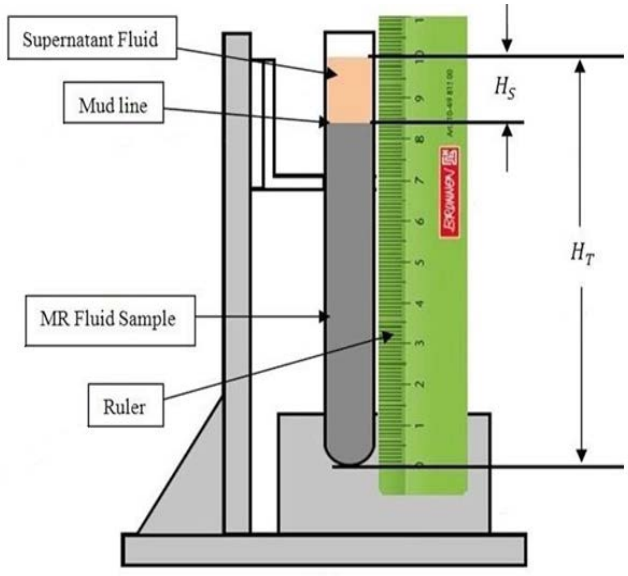

Figure 3. Experimental set up to determine sedimentation ratio[2].

Calibration of capillary tube viscometer can be done with the help of fluid like water, with no external magnetic field. We can directly compare the experimental data with standard values.

5.1 Factors Effecting viscosity of MR Fluid.

- Particle volume fraction.
- Temperature.

5.1.1 Partial Volume Fraction

When partial volume fraction increases the space between the particles decreases as a result the flow field of

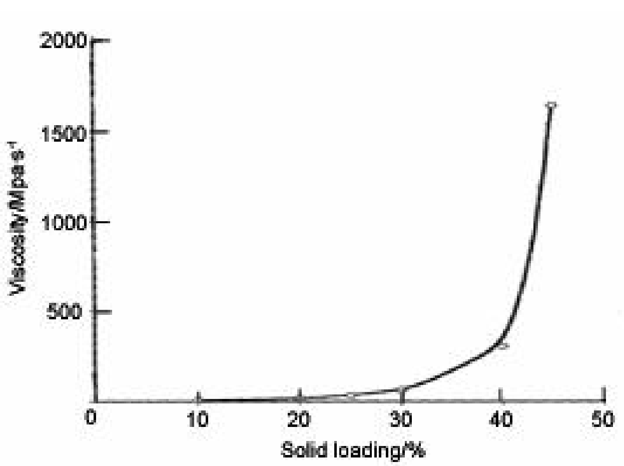

Figure 4. Effect on viscosity if solid loading is increased by 50%[12].

one particle is affected by other particles, also these particles experience hydrodynamic interaction as shown in Figure 4. If particle concentration is increased there is a rapid increase in viscosity, the friction like factor and the resistance to shear cause rapid increase in viscosity of MR Fluid[14,15].

5.1.2 Temperature

As shown in Figure 5 when temperature of MR Fluid is increased the density and viscosity of fluid decreases and thus it affects the stability of the MR Fluid. On the other hand when the temperature decreases the density and viscosity of fluid increased. Change in temperature also affect the thermal conductivity of the MR Fluid at low temperature thermal conductivity of MR Fluid increases and vice-versa, but with increase in magnetic field the effect of temperature diminishes and thermal conductivity reaches almost the same value for different temperature ranges.

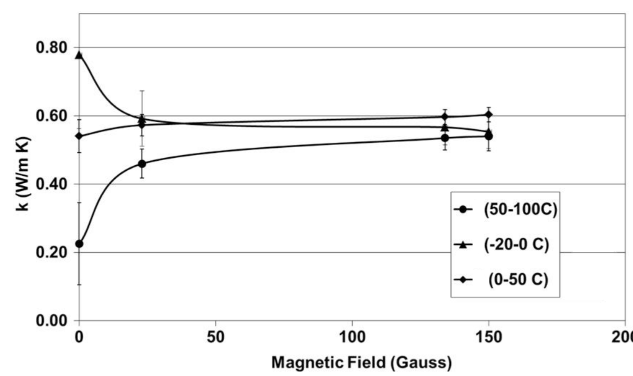

Figure 5. Thermal conductivity of MR Fluid at different temperature intervals[1].

6. Results and Discussion

Due to sedimentation homogeneity of magneto rheological fluid is influenced, particles settle down leaving oil in upper layer which is named as supernatant fluid (Hs). The sedimentation analysis is done visually by observing the position of mud line which is boundary between Hs and tribal part. Due to sedimentation homogeneity of magneto rheological fluid is influence, particles settle down leaving oil in upper layer which is named as supernatant fluid (Hs). The sedimentation analysis is done visually by observing the position of mud line which is boundary between Hs and tribal part.

7. Conclusion

- MR Fluids are prepared by adding Fe particles in a carrier fluid which can be silicone oil or any other depending upon the applications.
- Viscosity of the MR Fluid is varied with changing proportions of carrier fluid and Fe particles.
- Additives such as grease can be added to prevent sedimentation.
- With the help of permanent magnet response of MR Fluid is verified i.e. it reacts when comes in magnetic field.

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