Preparation of Magneto Rheological Fluid for Vibration Control

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Abstract: Magneto rheological (MR) fluids are a new kind of smart vibration mitigation material for vibration control, whose shear yield stress can change in magnetic field. The rheological properties, anti-settlement stability are the very important properties of MR fluids. In this paper, a kind of preparation process of MR fluids is introduced and MR fluids with different concentrations of carbonyl iron particles along with suitable additives are synthesized. Then the properties of self-prepared MR fluids are tested, including the sedimentation stability test and viscosity test. The results of the MR fluid property tests show that the adding of 10 micrometer sized carbonyl iron particles will improve the sedimentation rate of MR fluids.

Keywords* —*Molar Concentration, Sedimentation ratio (%), Viscosity index, Specific gravity, Carbonyl Iron.

I. INTRODUCTION

MR fluids are a kind of controllable fluid that were identified by the US National Bureau of Standards in 1948. MR fluids usually consist of micrometer-sized magnetic particles, a dielectric carrier fluid, and some stabilizing additives. When they are placed in an adjustable magnetic field, their yield stress changes with the magnetic field intensity. Having response time in a few milliseconds this property enables a quick response interface between mechanical systems and electronic components. Because of this kind of smart feature of MR fluids, they have been concerned by more and more researchers. Furthermore, Magneto-rheological fluid has very versatile application opportunities in many fields including aerospace, automotive industry, hydraulics, fields such as medical. MR fluids have been successfully used in intelligent vibration control, such as the building structures, the bridge structures, the automobile suspension system, the artificial or prosthetic limb, and military equipments.

The study of flow and deformation of fluids in which solid particles are dispersed is called as rheology. These types of fluids can be sludge, suspensions, mud, polymers or bodily fluids. The magneto-rheological fluids contain magnetizable particles, when these particles are dispersed in synthetic fluids they show a characteristic change in the properties that are highly sensitive and reversible in nature The MR fluid basically consist of carrier (base) oil, a binder, and the magnetizable particles. The base fluid is mixed with the binder along with the iron particles and stirred for long intervals, for proper dispersion and uniform concentration. The carrier fluid constitutes for a 50% to 80% of the volume in MR fluid, the ratio can be varied according to the requirement. The binder constitutes for 10% to 20% of the volume in an MR fluid and the rest of the volume is occupied by iron particles.

Typical magneto rheological fluids are the suspensions of micro magnetic particles (ferrous) suspended in an appropriate carrier liquid such as mineral oil, synthetic oil, water or ethylene glycol. The MR fluid is composed of following main components.

1) Carrier (base) fluid

2) Magnetizable metal particles

3) Binders and stabilizing additives

1) Base fluid

The base fluid is non-magnetic carrier fluid in which the metal particles are uniformly dispersed. The base fluid has properties of natural lubrication and has shock absorbing. To take maximum advantage of MR Fluid technology the base fluid must have a low viscosity and it should have high viscosity index. This is required for variation due to applied magnetic field to be more effective than natural viscosity. The presences of suspended particles make base fluid thicker. Commonly used base fluids are mineral oils, hydrocarbon oils, and Silicon oils.

2) Metal particles

For this phenomena to be useful, the suspended particles should be affected by the magnetic field quickly. For this, magnetizable metal particles are used. Metal particles used in the MR- fluid synthesis are very small, approximately of the order of 1 micrometer to 10 micrometer . Usually metal particles used are carbonyl iron, powder iron and iron cobalt alloys. Ferrous particles of these materials possess the ability of saturation at high magnetism which leads to form a solid magnetic chain. The particles can be up to 50% in the base fluid.

3) Additives

Certain additives are added to MR fluid for controlling its properties. These additives are infact surfactants and stabilizers. Surfactants lower the rate of settling of the metal particles. The functions of additives are to maintain friction between the metal particles, to control the viscosity of the fluid and to reduce the rate of settling of particles making the fluid thick due to long term use of the fluid. Thus additives also increase the working cycles of the MR fluid. Commonly used additives are lithium based grease and ferrous oleate. The MR behavior of the fluid is determined by varying composition of these three component.A proper combination of amount of these components is necessary to define the properties of the fluid.

II. PROCEDURE FOR PREPARATION OF MR FLUID

Material Used:

Carbonyl Iron Particles

The iron powder particles are easily magnetizable and are spherical in shape. The average particle size of these grains was approximately 4-10 µm as BASF norms. Along with that, iron powder particle’s purity was as high as 97.5%.

AP3 Grease

Grease is a semi-solid, which contains lubricating properties. The grease possesses a feature by which it has high initial viscosity and on application of shear force the viscosity drops and it gives the same effect of oil. This is the thixotropic nature of grease.

Sr. No	Properties	AP3 Grease
1	Maximum usable Temperature ^{0}C	135
2	Water Resistance	Excellent
3	Oil Separation	Good
4	Appearance	Buttery and Smooth
5	Protection Against Rust	Good

Table 1 : Properties of AP3 Grease

Silicone Oil (Base viscosity:0.33)

Sr No	Properties	Silicone Oil	Castor Oil
1	Viscosity (Pa.s)	0.031	0.03
2	Flash Point (^{0}C)	290	270
3	Specific gravity	1.01	0.959
4	Density (Kg/m^3)	971	914
5	Market Cost (Rs/25 gm)	120	80

Table 2 : Properties of Base oil

Instruments utilized:
Mechanical stirrer, Stopwatch, Weighing pan, Test tube, Measuring beaker ,Beaker, Beaker holder.

Figure 1.Mechanical Stirrer

A. Composition of ingredients for MR Fluid Sample 1:
Total mass of Fluid to be prepared = 100 gm

Sr. No.	Components	Wt. percent (%)	Mass (in gm)
1	Silicone Oil	52 %	52
2	AP3 Grease	8 %	8
3	CI Powder	40 %	40

Table 3 : Sample 1 Composition

Preparation Process for sample 1:

1. Preparation of mineral oil-based fluid: Mix silicone oil and AP3 grease in mechanical stirrer at:

a. First, 500 rpm for 90 minutes while adding grease gradually to the mixture.

b. Then at 1500 rpm for 15 minutes. Ensure that the mixture obtained is homogenous.

2. Synthesis of C.I mixture : Add CI powder (10 gm 97% purity) in small amounts while stirring at 600 rpm.

a. The CI powder is added in 5 parts after intervals of 30 min.

b. The mixture is allowed to stir for 2 hrs at 600rpm.

B. Composition of ingredients for MR Fluid Sample 2:

Total mass of fluid to prepare = 70gm

Sr. No.	Components	Wt. percent (%)	Mass (in gm)
1	Silicone Oil	60	42
2	Oleic Acid	10	7
3	CI Powder	30	21

Table 4 : Sample 2 Composition

Preparation Process for sample 2:

1. Preparation of mineral oil-based fluid: Mix silicone oil and Oleic acid at 800 rpm in mechanical stirrer for 45 minutes.

a. The oleic acid is gradually added in a time period of 25 minutes.

b. Ensure that a homogenous mixture is obtained at the end of the 45 minutes.

2. Synthesis of C.I mixture Add CI powder in small amounts while stirring at 1000 rpm.

a. The CI powder is added in 4 parts after intervals of 30 min.

3. The mixture is allowed to stir for 2 hrs at 1000 rpm.

C. Composition of ingredients for MR Fluid Sample 3:

Total mass of fluid to prepare = 70gm

Sr. No.	Component	Wt. percent (%)	Mass (in gm)
1	Silicone oil	55	38.5
2	Oleic acid	15	10.5
3	CI powder	30	21

Table 5 : Sample 3 Composition

Preparation Process for sample 3:

1. Preparation of mineral oil-based fluid: Mix silicone oil and Oleic acid at 800 rpm in mechanical stirrer for 60 minutes.

a. The oleic acid is gradually added in a time period of 25 minutes.

b. Ensure that a homogenous mixture is obtained at the end of the 60 minutes.

2. Synthesis of C.I mixture :Add CI powder in small amounts while stirring at 1000 rpm.

a. The CI powder is added in 4 parts after intervals of 30 min.

3. The mixture is allowed to stir for 4 hrs further at 1000 rpm.

III. SEDIMENTATION STABILITY TEST

The sedimentation stability of the MR fluids can be represented by the sedimentation rate, which can be defined as the ratio of the supernatant fluid volume to the mixture volume within a fixed period. The sedimentation ratio is defined as:

$$\text{Sedimentation ratio} = \frac{\text{volume of supernatant liquid}}{\text{volume of entire liquid}}$$

Three samples of MR fluids were placed in the three 10-ml graduated glass tubes, respectively, as shown in Fig 2. The volume of the supernatant liquid was obtained by observing the phase boundary between the supernatant liquid and the concentrated suspension until this volume reached an asymptotic value. Figure 2b shows the sedimentation stability of the MR fluids samples with different amount of 10 _m-CI particles. It can be seen from the figure that the sedimentation rates of all the samples were relatively large during the first three days and then the rate slowed and tended to be constant after ten days. At the same time, it can be seen that the initial sedimentation rate of the sample D is much less than that of the sample C, B, and A. The average final sedimentation rate of the sample A, B, C, and D were 18.2%, 14.9%, 14.1%, and 9.8%, respectively. And the average final sedimentation rate of the sample D was 8.4%, 5.1%, 4.3% less than that of the sample A, B, C, respectively.

The results show that the sedimentation stability of the MR fluids is relevant to

- ❖ The sedimentation tests were carried out by placing the samples obtained in test tubes immediately after their synthesis.
- ❖ After fixed time intervals, the lengths of the clear part and the turbid part are measured.
- ❖ Sedimentation ratio is defined as the ratio of the supernatant fluid (clear part) to the turbid part of the fluid.
- ❖ Equivalently they can be calculated as the ratio of the lengths of the supernatant liquid and the total liquid column height.

Sample	Volume (ml)	Mass measured (gm)	Density (gm/cc)
Sample 1	20	31.11	1.1625
Sample 2	20	21.04	1.052
Sample 3	20	23.25	1.55

Table 6 : Sample Comparision

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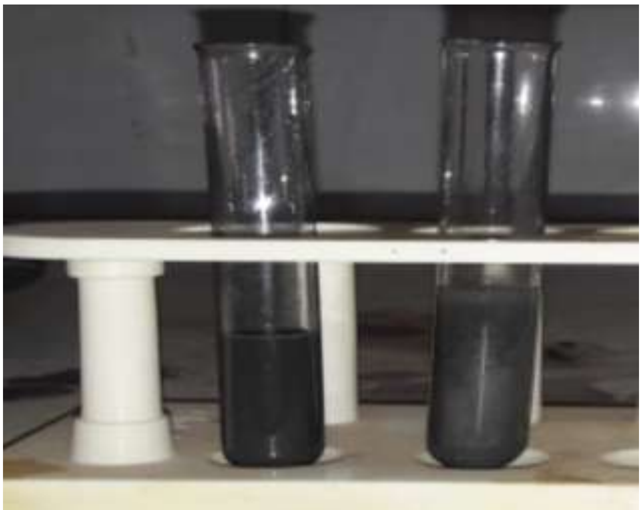

Figure 2. Sample 1 and Sample 2

Figure 3.Sample 1 and Sample 2

IV. RESULTS

Sample 1 Reading (After 120 minutes)
Total Length = 56 mm
Clear (part) Length = 27.9 mm
Turbid (part) Length = 28.1 mm

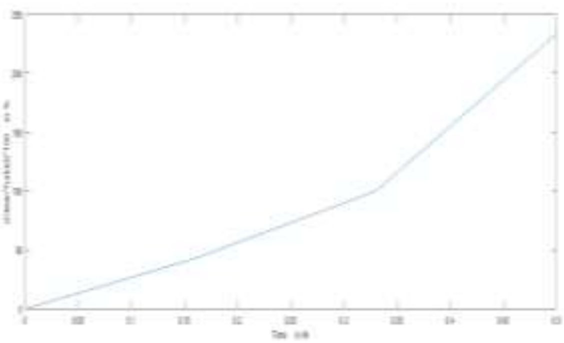

Figure 4 : Sample 1 Sedimentation Rate

Sample 2 Reading (After time 4 hr)
Total Length = 58 mm
Clear (part) Length = 3.5mm
Turbid (part) Length = 62 mm

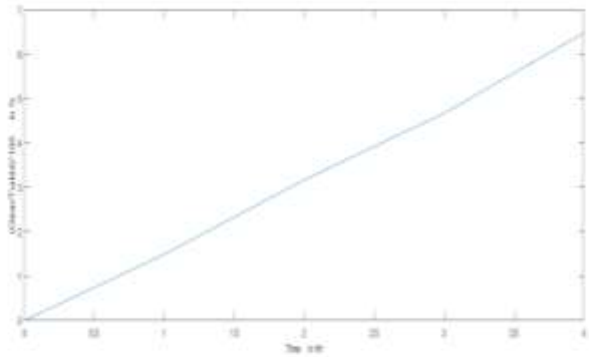

Figure 5 : Sample 2 Sedimentation Rate

Sample 3 Reading (After time 4 hr)
Total Length = 64 mm
Clear (part) Length = 2 mm
Turbid (part) Length = 62 mm

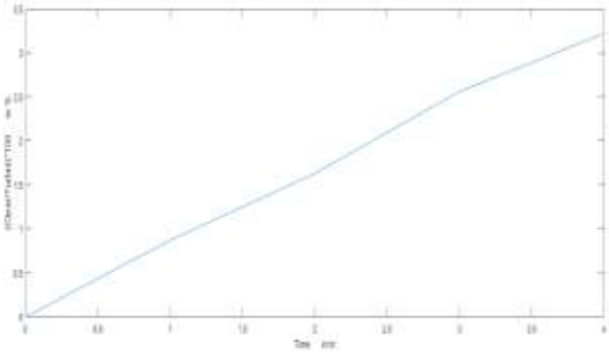

Figure 6 : Sample 3 Sedimentation Rate

V. CONCLUSION

In this study, MR fluids were prepared with the appropriate ingredients and process. The 10 µm-CI particles were used to study the effect of the size on the MR fluids performance. To investigate the performance of the MR fluids and determine the effect of 10 µm-CI particles sedimentation stability.

1. The settlement results show that the sedimentation stability of MR fluids are function of grain diameter of the CI particles. The smaller the particle size, the slower the settlement.

2. The sedimentation rate is dependent on relative composition of binder and C.I particles. It can be observed that binder composition greater than 10% has effective impact on mitigating sedimentation rate.

3. Also the type of binder ingredient used affects the mitigation of settlement rate. Oleic acid having composition 15% has the least settlement, whereas AP3 grease used in limited quantity has maximum settlement.

4.For homogeneous sample preparation the time required for mixing carrier fluid and binder should be more than 75 min. While addition of C.I particles should be in equally small quantities at optimum frequency of 25-30 min for uniform coating of C.I particles with binder.

5.Sedimentation rate can also be minimized using AP3 Grease and allowing uniform coating on C.I particles for longer duration of 2-2.5 hrs.

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