CHANGE IN SEDIMENTATION RATE OF MR FLUID WITH DIFFERENT BASE FLUIDS

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Abstract: MR fluids represent a class of smart materials that respond to an applied electric or magnetic field with a dramatic change in rheological behavior. The main advantage of MR dampers is that they require very little control power, have simple construction, quick response to control signal, and only few moving parts. MR fluid has become really popular in the last twenty years due to their efficiency and application in many fields. In this paper, we are using different compositions of base fluid such as Silicone Oil, Lubricant Oil, and Grease to study the effect on the sedimentation rate of each fluid. Each composition is mixed with carbonyl Iron powder as well as oleic acid as surfactant and kept in a test tube for 15 Hours. It can be observed that the composition with silicone oil as the base fluid has the least sedimentation rate.

Keywords: **Magnetorheological fluid, Preparation of MR fluid, Sedimentation rate, Base fluid**

I. INTRODUCTION

Magneto-rheological materials including fluids belong to a class of smart materials called rheological materials that change their properties as a function of magnetic field [1]. The speciality of MR fluid is that under an external magnetic field the fluid act as a semisolid material because of the increase in its apparent viscosity. However, if we remove the magnetic field, the suspension turns into a fluid in few milliseconds, and these highly reversible transitions provide the feature of magnetic field controllability of the flow of MR fluids. Thus, MR fluid, a rheological material whose viscosity undergoes apparent changes on application of magnetic field, is considered as a smart material. These materials can be used for active and semi-active control of engineering systems [1].

This paper discusses the preparation of MR fluid in a cost-effective way by carefully choosing the required components, and we also observe the change in sedimentation rate of MR fluid by changing the carrier fluid or base fluid. For this study, different ratios of base fluid, magnetic particle, and additives are used suited for each of the base fluid.

II. LITERATURE SURVEY

Jacob Rabinow developed MR fluid between 1940-1945 at the National Bureau of Standards (NBS), MP fluid is suspensions of micro-sized, magnetizable particles of 0.5 to 10μm in a carrier liquid.[10]and could be in variable configurations of weights of 20-80%. Jolly et al. states that MR fluids are considered to be a smart material for the rheological properties; as the material experience a magnetic field it changes its properties from a liquid to a semi-solid state. [11].
Similar to the ER fluids, MR fluids are non-corrosive, irreversible flocculation and with high magnetic saturation with a large field-induced yield stress, but minute apparent viscosity without the application of the magnetic field.[12]MR fluids should use an external magnetic field like ferrimagnetic, paramagnetic, and ferromagnetic materials could be used [10].

While discussing the making of the MR fluid it can be observed that silicon oil is a much more suitable candidate for base fluid. This is due to properties like low friction, and the sedimentation rate of the fluid is varied with the addition of additives. Additives such as ferrous naphthenate, ferrous oleate, or oleic acid are used to reduce the clumping effect and reduce the sedimentation rate. This paper discusses the change in sedimentation rate by changing the base fluid and keeping the additive constant for all mixture. This will help us identify why silicone oil is preferred over other base fluids and how much difference in sedimentation rate can be observed.

III. METHODOLOGY

The major objective of the proposed methodology is to obtain magnetorheological fluid with reduces sedimentation rate, by experinmenting different ratio of its components.
MR Fluid, like all other smart fluids, features a large particle size and as a result, these particles form hard cakes by settling at the bottom because of the gravitational pull, this affects the fluid losing its ability to change viscosity with the change in magnetic-field because there would be no particles left in the fluid that can be aligned with the magnetic field. It is necessary to measure the concentration of particles at regular intervals of time and at various height of the fluid [13]. There are two distinct phases included while preparing MR fluid: solid phase and liquid phase[14]. In the solid phase, the particles are covered with some additives in a specific composition to increase the volume to mass ratio of the particles. In the liquid phase similar additives are added to the carrier fluid in a specific manner and ratio to increase the density of the carrier fluid.

- The solid phase is then mixed with the liquid phase for a certain period.
- The resulting mixture is then left undisturbed to observe the sedimentation characteristics of the fluid.

- The addition of stabilizers and additives often overcomes the problem of sedimentation[1].

IV. COMPOSITION OF MR FLUID

Generally, there are three basic components in a conventional MR fluid.

Base fluid, solvent, or carrier oil is a non-magnetizable liquid which combines lubrication and damping features. The carrier fluid shoul be examined carefully considering the significant effect of nonmagnetic media on rheological characteristics of the magnetorheological fluid [6]. To maximize the MR effect, the carrier oil should be low-viscous and insensitive to temperature changes, so that during the off-state the MR effect is the dominant factor in creating shear stress. There are various types of liquids which can be utilized including hydrocarbon, mineral, silicone, and hydraulic oils; silicone copolymers, polyester, polyether; halogenated organic liquids, diesters, polyoxyalkylenes, fluorinated silicones, glycols, and water. A combination of these fluids may also be used as the carrier component of theMR fluid.

Mineral oil, silicone oil, or any synthetic oil is preferred owing to its properties like low viscosity, low friction characteristics,high shear strength, and high flash point [8].

Fig.1 Silicone oil

Ferromagnetic particles: Alignment of these particles along a path of magnetic field causes the MR effect. The most common magnetic particles used are iron, iron/cobalt alloys, iron oxides, iron nitride, iron carbide, and carbonyl iron. For this study, Iron carbonyl powder is used. These particles yield high magnetic saturation values in the order of Magnetic materials can take as high as 50% of the total volume. Increasing the volume fraction of magnetic material and employing a rapid compression-assisted-aggregation process can force MR fluids to form a microstructure and highly affect yield shear stress in MR fluids.

Fig.2 Iron carbonyl powder

The additives: Few different additives can be used in MR fluids including surfactants, nanoparticles, Nano magnetizable, or coating magnetizable particles. Additives are suspending compounds, with shear thinning property and ability to modify friction which should be anti-corrosion/wear. Thixotropic materials such as grease, metal soaps, lithium stearate, or sodium stearate have high viscosities in static conditions and becomethin over time when shaken, agitated, or otherwise stressed. These materials are very effective in preventing caking or particle sedimentation and can alleviate the settling problem. Additives such as ferrous naphthenateor ferrous oleate can be used as dispersing agents to prevent clumping.

Oleic acid is used as a surfactant. It is generally used to reduce particle agglomeration. However, it can also change the sedimentation behavior of MR Fluid.

Fig.3 Oleic acid

Table 1: Composition of MR fluid with different combination

Samples (Magnetorheological fluid)	Carrier Fluid (Base fluid)	Carrier Fluid (wt. %)	Carbonyl iron powder (3µm) (wt. %)	Surfactant (Oleic acid) (wt. %)
Sample A	**Silicone oil**	**57.5%**	**40%**	**2.5%**
Sample B	**Lubricant oil**	**73%**	**25%**	**2%**
Sample C	**Grease**	**78.5%**	**20%**	**1.5%**

4.1 Preparation and Mixing of MR Fluid

For the preparation of MR fluid the Iron carbonyl powder is first coated with guar gum or any other additives to increase the volume to mass ratio of particles, then the Base fluid is added along with a surfactant which in this case is Oleic acid.
After the composition of fluid with the ratios given in table 1, next step is to mix it properly so that the components will be uniformly distributed throughout the fluid and the sedimentation will also be reduced.

For mixing the solution we used a centrifugal mixer, a Rotary flask shaker, and a DIY rotary machine. The mixture was first mixed in centrifugal mixer for two hours after which the rotary flask shaker was used for 3 hours and at the end, we used the rotary machine to mix the mixture for six hours. The over usage of time in mixing the mixture can be reduced by using an electric mixture, which will reduce the time to 2-3 hours [9], but the unavailability of an electric mixture was compensated by using different apparatus and mixing for a higher duration of time.

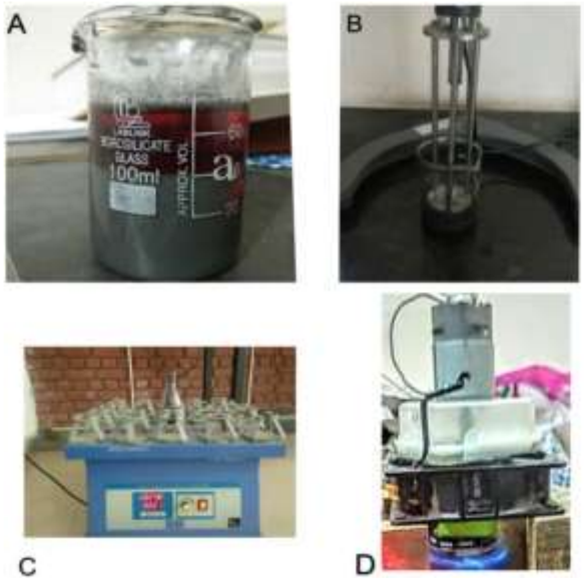

Fig.4 Mixing of Fluid using different apparatus

V. SEDIMENTATION OF MR FLUID

Particle sedimentation is one of the main issues affecting magnetorheological fluids (MRF) [2]. This is caused by the ferroparticles settling over time because of the difference in inherent density of both the particles and the base fluid The rate of sedimentation of the particles is a primary issue considered while implementing a MR device such as a damper or any suspension system. Surfactants are typically used to offset this effect, but at a cost of the fluid's magnetic saturation [5]. Good compatibility of additives with the carrier and the iron particles reduces sedimentation rate and irreversible agglomeration of particles [3]. For this study, we have used a centrifugal mixer, rotary flask, and an ordinary rotor as a centrifugal accelerator, and experimentally compared the sedimentation ratio achieved by it with ratios obtained under gravity.

The three samples A, B, and C contains silicone oil, lubricant oil, and grease as the base fluid respectively. The samples observed immediately after mixing show no sedimentation, but after leaving the samples for 15 hours it is observed that sample A shows the least sedimentation, which contains silicone oil as the base fluid.

VI. RESULTS AND DISCUSSION

It can be observed from the experiment that sample A containing 57% by wt. silicone oil as base fluid with 40% of carbonyl iron particles and surfactant concentration of 2.5% by wt. showed the least sedimentation rate among the three samples. All three samples were mixed and collected in a test tube to rest for 15 hours to check the sedimentation caused by gravity. This clearly shows that choosing the right carrier fluid and addition of additives partially helps in overcoming the sedimentation problem due to density difference among suspended particles and carrier fluid [1]. It can be observed that while the mixture with lubricant oil and grease started to sediment within two and four hours respectively, the mixture with silicone oil as base fluid started sedimenting only after 24 hours.

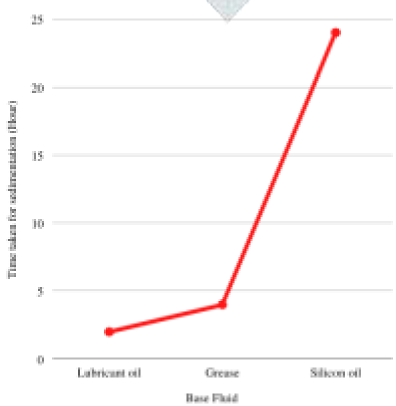

Fig.6 Different base fluids and their sedimentation rate

VII. CONCLUSION

Nowadays, MR fluid is used for many applications including automobile suspensions, exercise equipment, polishing machines, and so on, and because of its growing popularity and applications, many scientists and researchers are working on MR fluid to make it more accessible and affordable without compromising its efficiency. The main challenge in preparing MR fluid is reducing sedimentation due to gravity and increasing the yield stress [15]. These challenges can be tackled by adding suitable additives and base fluids to the fluid.

This paper studies the effect of base fluid or carrier fluid on the sedimentation rate of MR fluid. It can be observed from the experiment that while choosing between silicone oil, lubricating oil, and grease as base fluid, silicone oil provides the least sedimentation rate suitable for MR fluid, and the difference in sedimentation between silicone oil and the other two are very high.

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