1. Introduction

MR fluids are keen materials produced using magnetic particles that can change their stream properties under the impact of magnetic field. A movable thickness, fast reaction to time and high element stream quality are its primary characteristics. Shrewd materials have different properties like they can be all of a sudden changed in a controlled state by outer powers, for example, attractive field or electric fields and so forth.

An MR fluid is a suspension of micro sized iron particles in base fluid, which show changes in its behavior and properties when placed in the influence of external magnetic field. The fluid may change to solid and back to liquid on application of magnetic field or vice versa.

Iron powder is used commonly in preparation of MR fluid since it property of high saturation of magnetization. When a magnetic field is applied, iron particles arrange themselves in strong chains and fluxes. Therefore chains formed by particles act as a barrier to the flow of fluid and hence change the properties of fluid.

Base fluid, metal particles and additives are the three important components required for the synthesis of MR fluids. The base fluid acts as a carrier for the iron particles. For high saturation point, the viscosity should be small to an MR fluid and independent to the temperature. Without magnetic field, MR fluids behave as base fluids according to their chemical composition.

The first patent for MR liquid received by Rabinow is identified with applying torque electro-attractively controlled gadget on-state rheological properties which has been explored by SevelGenc. The possibility of normal molecule measure and other attractive properties have been talked about by the creator. Additionally the volume part of a MR liquid and its different consequences for the rheological properties in on and off states have

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been talked about by Golden MA. The examination of sedimentation by utilizing extensive molecule measure and the consistency of the liquid at zero attractive field was talked about by Phule. Foistere has examined about the determination of various segments of MR liquid relying on their properties, impact of various segments on rheology of fluids. Zaman examined about the strategy for how to acquire high turn up proportion by utilizing volume division of particle and clarified that how settled size proportion is expanded when least consistency is gotten at higher volume proportion of the little particles. Jolly MR has observed several MR fluids and discussed their behavior and magnetic properties. Wereley discussed the Iron particles at Nano and Micron scale, in order to produce high octane packing structure of small particle. The objective of this research work is synthesis and characterization of MR fluid. These fluids can be used for various applications in medical science and mechanical engineering upon suitability.

2. Different Modes of Operation

In many applications the MR fluids are employed in one out of three common modes of operation.

- Flow mode
- Shear mode
- Squeeze flow mode

In all these modes, fluid flow is a result of pressure gradient between the two fixed plates, fluid between two plates moving relative to each other, fluid between plates which moves in the direction perpendicular to their respective planes. In all these cases magnetic field is applied in orthogonal direction to the planes of the plate, so that the fluid can be restricted in the direction symmetrical to the plates. On the basis of modes of operation MR fluids are widely used in number of areas in technology such as shock absorbers, brakes, clutches, engine mounts, alternators, control valves, vibration damping, optical finishing, in Medical applications for the treatment of cancer targeted magnetic hyperthermia etc.

2.1 Base Fluid

Base fluid is a carrier fluid which is magnetically neutral and is used to carry metal particles. The base fluid should be independent to temperature and having low viscosity. The permeability of base fluid should be low so that metal particles remain suspended in the base fluid. When iron particles are added to the base fluid then it becomes thicker, so it is important that the base fluid should have neutral lubricating and damping features so that the metal particles remains suspended and it will reduce settling down of metal in MR fluid. This will also increase the physical properties of the MR fluid. From the literature survey the commonly used base fluids are mineral oils, hydrocarbon oils and silicone oils.

2.2 Metal Particles

Metal particle in the MR fluid is the main component which affects the strength of an MR fluid. These particles should be easily magnetized when external field is applied. On the removal of applied magnetic field these particles should be demagnetize, i.e., saturation magnetization of metal particles should be high, so that metal particles remain dispersed in the base fluid without clustering. Alloys of cobalt and iron are the most suitable metal particles for the preparation of MR fluid. The saturation magnetization of these alloys are approximately 2 Tesla, but these are costly for practical applications. On the basis of literature survey commonly used metal particles are powder iron, carbonyl iron and iron cobalt alloys. We choose iron particles of size less than 53µ. The important characteristics of the metal particles are particle size, shape, saturation magnetization and coercive field.

Iron particles of 53µ size are produced with the help of grain fineness testing machine. In this machine the iron powder is poured from the top and then machine is allowed to vibrate for 10 minutes. When the machine stops all the iron particles of 53µ size are collected in 300 mesh size tray.

2.3 Additives

Additives is the another important component of the MR fluid which is used in it for many purposes, e.g. to minimize sedimentation, minimizing coagulating of the particles. In order to improve the stability and rheological properties additives are added to MR fluid. They include the surfactants and stabilizers. Surfactants are added to MR fluids to decrease sedimentation of metal particles. Sedimentation is the main aspect to be prevented. For
practical purpose the sedimentation rate should be kept at low. Grease is a good additive with base fluid silicone oil. The white lithium grease is used in many automobile applications. Therefore it is used as an additive for the fluid sample.

3. Preparation of MR Fluid Samples

For the preparation of MR fluid samples, the composition of material is fixed. After a detailed literature survey, two methods for the preparation of MR fluid are found (i) volume percentage and (ii) weight percentage. By using different weight of MR fluid constituents three samples are prepared. The levels are fixed for preparing our three samples which are shown in Table-1.

According to the above three combinations the MR fluid samples are prepared. The prepared fluids appear similar as black paint. This prepared fluid is MR fluid.

4. Sedimentation Analysis

Practical issue with MR liquid now a day is settling down of metal particles. Sedimentation is the inclination of the particles to settle down at the base of the fluid in which then stop against an obstruction.

In MR liquid the sedimentation is controlled by ignoring the components of attractive consequences for the MR fluid particles. Because of sedimentation homogeneity of MR fluid is impact, particles settle down leaving oil in upper layer which is named as supernatant liquid (HS). The sedimentation investigation is done outwardly by watching the position of mud line which is limit among HS and tribal part.

Arranged MR liquid examples were filled upto 10cm in a tube shaped glass test tube and tests are held vertically. The tallness of the supernatant liquid (HS) is measured after at regular intervals with the assistance of stop watch and ruler. Thus the sedimentation proportion SR is characterized as the proportion of the supernatant oil (HS) to the aggregate stature of MR liquid (HT) filled in a given tube it can be communicated as,

\[ SR = \frac{H_S}{H_T} \times 100\% \]

Where, SR is the sedimentation ratio, \( H_S \) = height of the supernatant fluid and \( H_T \) = total height of fluid filled in the tube.

Figure 1 shows the rate of sedimentation of iron particles with various additive %age in MR fluid sample (Table-1). Here we need to remember more is the content of iron particles more will be the effect on MR Fluid. Figure 2 shows MRF-3 sample has the fastest sedimentation as compared to the other samples which leaves a small fraction of iron particles in the supernatant fluid but later on has less sedimentation ratio. The amount of grease is 10 gm against 50gm of iron particles in the MRF-3 sample. The sample MRF-1 having lesser SR in the beginning of the experiment. The amount of grease is 6gm against 36gm of iron particle (Table-1) in sample MRF-1. From above observation it can be observed that the grease has a grasp on the sedimentation ratio of MR fluids. By increasing the percentage of grease the sedimentation is decreased. It describes that by increasing the percentage of additives increases the stability of MR fluids.
Table 1. Composition of MRF samples according their weight percentage

| Sample Name | Fe particle (gm) | Silicone oil (gm) | Grease (gm) |
|-------------|------------------|------------------|-------------|
| MRF-A       | 36               | 58               | 6           |
| MRF-B       | 40               | 52               | 8           |
| MRF-C       | 50               | 40               | 10          |

5. Effect of Temperature on Viscosity of MRF

The effect of temperature on viscosity of MRF have been investigated. With rise in the temperature from 35-100°C, figure 3 shows the effect of temperature on the viscosity of MRF samples. The viscosity of MRF is increases with increase the volume concentration of the iron particles. It decreases with increase in the temperature. It has been observed that decrease is greatest at high temperature than the less value of temperature. In the study the thermal conductivity and viscosity of Al2O3 engine nanocoolant have been investigated. It is found that the volume concentration have significant effects on thermal conductivity and viscosity. Results indicates that viscosity and thermal conductivity increases with increase of the volume concentration(%) [5].

6. Conclusions

In this paper it is described that how MR fluid samples can be prepared containing different weight composition, therefore with different levels of constituent three samples are prepared. These samples are tested for its sedimentation and thermal properties. The average size of iron particle is found to be 23µm. The three samples are analyzed for SR. It is observed that the percentage of grease affect the SR. Higher the content of grease results lower SR and vice versa. It implies that as increase in percentage of grease provide better stability to MR fluid. It is indicated that with increase in the temperature the viscosity of MRF decreases. It has been observed that decrease is greatest at high temperature than the less value of temperature.

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