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Characterization of Hydro-Carbon Based Magneto-Rheological Fluid (MRF)

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Abstract: Magneto-rheological fluids (or simply "MR" fluids) belong to the class of controllable fluids. The essential characteristic of MR fluids is their ability to reversibly change from free-flowing, linear viscous liquids to semi-solids having controllable yield strength in milliseconds when exposed to a magnetic field. This feature provides simple, quiet, rapid response interfaces between electronic controls and mechanical systems. MR fluid dampers are relatively new semi-active devices that utilize MR fluids to provide controllable damping forces. The focus of this work is to synthesize and characterize the MR fluids. The first phase of the work (i.e., synthesis) involves the mixture of carrier fluid, iron particles and additives in measured quantities to form an MR fluid. This is then followed by the second phase (i.e., characterization) where the synthesized MR fluids are characterized using a suitable damper to obtain the force-velocity, pressure-velocity and variable input current behavior.

Keywords: Synthesis, Characterization, MR Fluids, MR Damper

I. INTRODUCTION

Field responsive fluids include magneto rheological (MR) fluids, ferro fluids and electro rheological fluids. A common property of these materials is that, in most cases, they are all dispersions of particles in a carrier liquid and some aspect of their theology is controlled by an external electric or magnetic field [1-3]. Typical magneto rheological fluids are the suspensions of micron sized, magnetizable particles (iron, iron oxide, iron nitride, iron carbide, reduced carbonyl iron, unreduced carbonyl iron, chromium dioxide, low-carbon steel, silicon steel, nickel, cobalt, and combinations thereof [4]) suspended in an appropriate carrier liquid such as mineral oil, synthetic oil, water or ethylene glycol. The carrier fluid serves as a dispersed medium and ensures the homogeneity of particles in the fluid [5]. Typically, the diameter of the magnetizable particles range from 3 to 5 microns [6,7]. The ultimate strength of an MR fluid depends on the square of the saturation magnetization of the suspended particle. The best available particles are alloys of iron and cobalt that have saturation magnetization of about 2.4T. Unfortunately, such alloys are expensive for most practical applications. The best practical particles are simply pure iron having a saturation magnetization of 2.15T. Virtually all other metals, alloys and oxides have saturation magnetization significantly lower than that of iron, resulting in substantially weaker MR fluids. A key to the magnetorheological response of MR fluids lies in the fact that the polarisation induced in the suspended particles by application of an external magnetic field. The interaction between the resulting induced dipoles causes the particles to form columnar structures, parallel to the applied field, as shown in Figure 1 [8]. These chain-like structures restrict the motion of the fluid hence increase the viscous characteristics of the suspension.

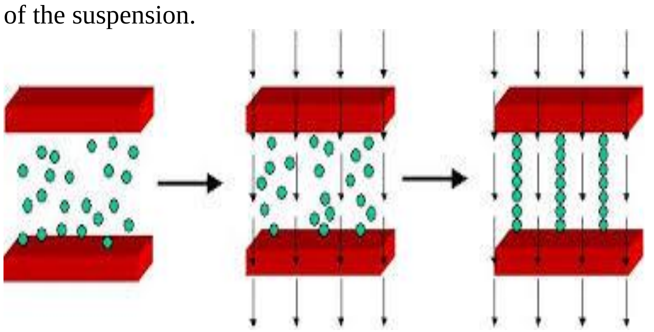

Fig: 1. Activation of MR fluid

In essence, MR fluid behaviour transforms from that of a liquid to that of a solid-like gel when an external magnetic field is applied. The dramatic transformation of MR fluids can be quite fast, on the order of 10e-3 and 10e-4 seconds, therefore, the MR fluids can be used as actuators in various damping schemes [9]. The ability to change the yield strength of MR fluids according to the magnetic field enables MR fluids to alter the structural damping and stiffness coefficients, therefore to make the structure "smart" or "intelligent" [7,10]. The properties of magnetorheological (MR) fluids allow their use in many commercially available products. Examples include small, linear dampers for real-time [11,12], semi-active vibration control in vehicles, rotary brakes [13], large linear dampers for semi-active control of seismic motions in buildings and bridges, magnetic abrasive flow machining, magnetic float polishing [14,15] and special purpose devices for rehabilitation process support [16].

II. SYNTHESIS & CHARACTERIZATION

Mentioned in the introduction are the materials required for the synthesis of an MR fluid. The concentration of these materials plays a vital role as the properties of the MR fluid depend on these concentrations. The properties are subject to change if different concentrations of carrier fluid, magnetic particles and additives are used. For the current study, two MR fluids were prepared using two different concentrations (by volume) of magnetic particles.

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The first concentration of MR fluid incorporates 40% by volume of magnetic particles. These are carbon based iron particles and are called as carbonyl iron particles. They were mixed with the carrier fluid (i.e. Hydro-Carbon) only and kept undisturbed for a period of five days to observe the gravitational settling. It was observed that the particles settled approximately 120 ml in a period of 5 days from the total height of the fluid column. Figure 2 shows the gravitational settling of carbonyl iron particles.

Fig: 2. Gravitational settling of iron particles

Later, additives were added to the mixture of iron particles and carrier fluid. The gravitational settling in this case was observed to be less than the settling of particles without the additives. This decrease in the settling of iron particles depicts the importance of the additives in an MR fluid. The particles in the former case settled hard and were not easily re-dispersible when compared to the latter case. Hence, it can be said that the additives added to the MR fluid enhanced the lubricity and modified the viscosity. Figure 3(right side container) shows the synthesized MR fluid for 40% by volume concentration of iron particles inclusive of additives (MRF-1).

Fig: 3. MRF-1&MRF-2

The second concentration of MR fluid incorporates 36% by volume of iron particles. As the gravitational settling was observed in the synthesis of the first fluid, the second MR fluid was synthesized by directly mixing the carrier fluid and additives with the iron particles. Figure 3(left side container) shows the synthesized MR fluid pertaining to 36% by volume iron particles (MRF-2). The MR fluids synthesized have different concentrations of iron particles. Depending upon the apparatus available to measure the concentration of iron particles, 100 ml of particles were measured while synthesizing both fluids and appropriate concentration of carrier fluid was added, to both, in order to balance the ratio of 40-60 for the first MR fluid and 36-64 for the second MR fluid. Here comes the concept of porosity into picture. The MR fluid with high concentration of iron particles, i.e. 40%, is more porous than the MR fluid with low concentration of iron particles, i.e. 36%. This can be observed from figures 3 where the final quantity of the mixture of MR fluid is different in both cases. The quantity of the MR fluid with 40% by volume of iron particles is less when compared to the quantity of the MR fluid with 36% by volume of iron particles even though the total quantity of the concentration of iron particles and carrier fluid was same. This is due to the presence of large number of pores for MR fluid with 40% by volume of iron particles.

III. EXPERIMENTAL SETUP

After being synthesized, these fluids were characterized using the experimental setup available at MJCET, Hyderabad. It consists of a damper, hydraulic system, sensors, data acquisition system and power supply. A brief description of each is presented in the subsequent paragraphs.

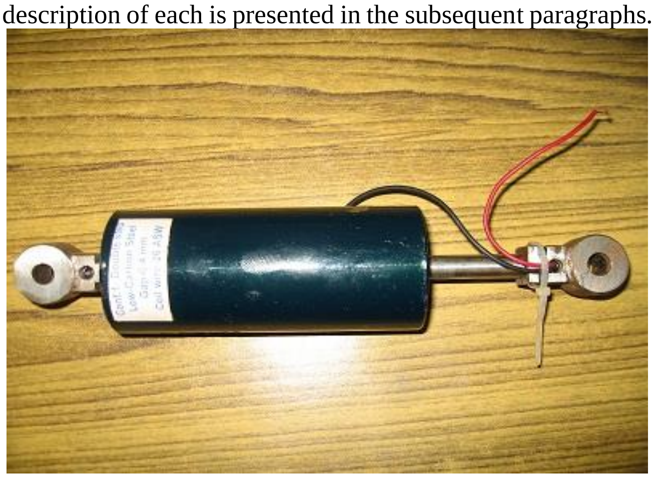

Fig: 4. MRF-DAMPER

The details of the experimental setup are shown in figure 5. The description of the equipment used for testing is discussed as follows:

Hydraulic system: The damper is driven by an actuator configured with two 10-gpm Moog servo valves with a bandwidth of 60 Hz. The actuator has a 50 mm diameter cylinder and a 40 mm stroke and is fitted with low-friction Teflon seals to reduce nonlinear effects and it was built by Denison Hydraulics India Limited, Hyderabad. The actuator is controlled by a servo-hydraulic controller in displacement feedback mode.

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The maximum speed under this configuration was 20 cm/sec.

Sensors: A position sensor, manufactured by OPKON (Model LPT), was employed to measure the damper displacement. The position sensor has a full range of 1000 mm displacement, speed of 2 m/s and repeatability $\leq 0.05\%$. A load cell of tension and compression type, made by OIML and rated at 20 KN, was used to measure the damper resisting force. The input current going into the MR damper coils was measured by a Tektronix current probe with a sensitivity of 100 mV/A. The pressure difference on either side of the damper piston was measured by two pressure transmitters, made by SPY, have a maximum range of 200 bars. Additionally, a Fluke 80T-IR infrared temperature probe with a sensitivity of 1 mV/°C was utilized to monitor the damper temperature during the experiment.

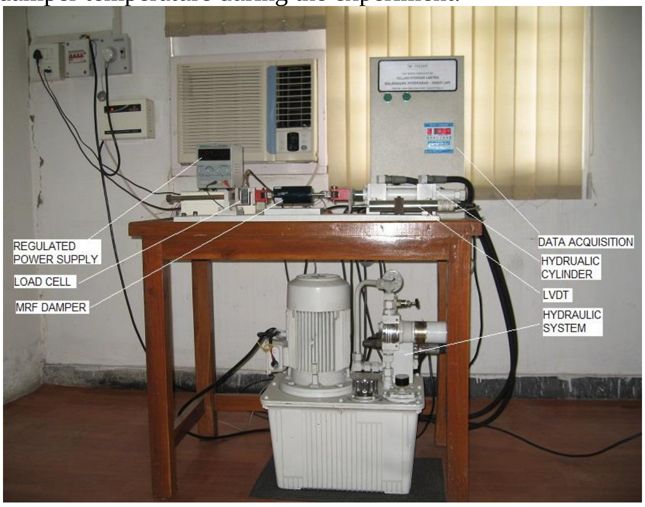

Fig:5. Experimental setup of MRF damper

Data acquisition: A data logger (Model: TC-800D) with 8 analogue inputs, manufactured by AMBETRONICS, was employed for data acquisition and analysis.

Power supply: A regulated power supply (Model: BK-150200) was employed to provide DC power supply with a full capacity of 2 amps to input current to the MR damper coils for quasi-static damper testing.

IV. RESULTS & DISCUSSIONS

As mentioned above force &pressure-velocity and variable input current effect tests were conducted using the setup shown above to investigate the behavior of the synthesized MR fluids. In the experiment, velocities of 0.00, 0.05, 0.1, 0.15 and 0.2 m/s were employed. The input current to the damper coil was constant at 0, 0.5, 1, 1.5 and 2 A respectively.

Force & Pressure-Velocity Behavior: The measured force-velocity behavior of the synthesized MR fluids at various constant input current levels are plotted and shown in figure 6. The following observations are made from the results:

i) A larger damping force is observed at high velocity. This may be due to the plastic viscous force.

ii) All the plots are almost parallel to each other and have very less slope. This indicates that the resistive force (F) of the MR damper is less dependent upon velocity (Vp).

iii) Larger damping force is observed with MRF-1 for all values of constant input current levels. This is due to the high concentration of magnetic particles present in MRF-1 when compared to MRF-2.

iv) It is observed that the resisting force of the damper on the either side of the mid position is not same.

Pressure-velocity behavior of the two MR fluids at different constant input current levels are also plotted and are shown in figure 7. Similar kind of behavior is observed in this case as well.

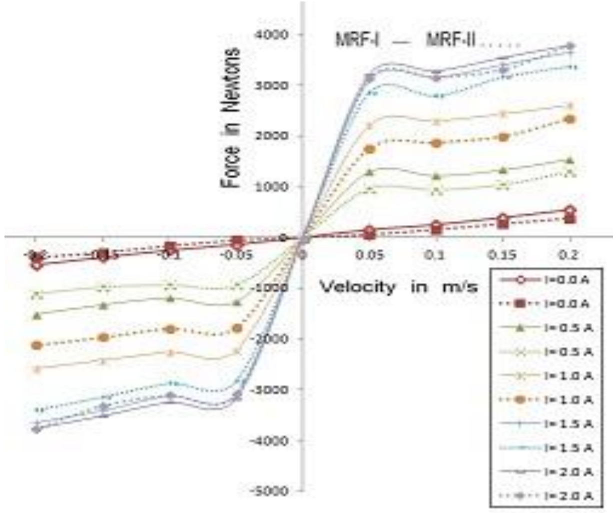

Fig:6. Variation of Force (F) wrt Velocity(Vp)

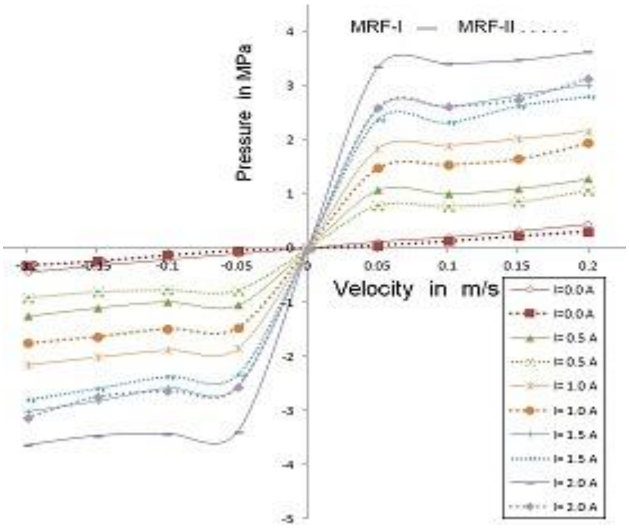

Fig:7. Variation of Pressure (P) wrt Velocity(Vp)

Variable Input Current Behavior : Force-current and pressure-current tests for the synthesized MR fluids at different constant velocity levels were conducted and results plotted in figures 8&9. The following observations were made:

i) All the plots are clustered and have more slope, i.e. the effect of piston velocity (Vp) on the damper resisting force (F)/pressure (P) is much less compared to the damper input current (I).

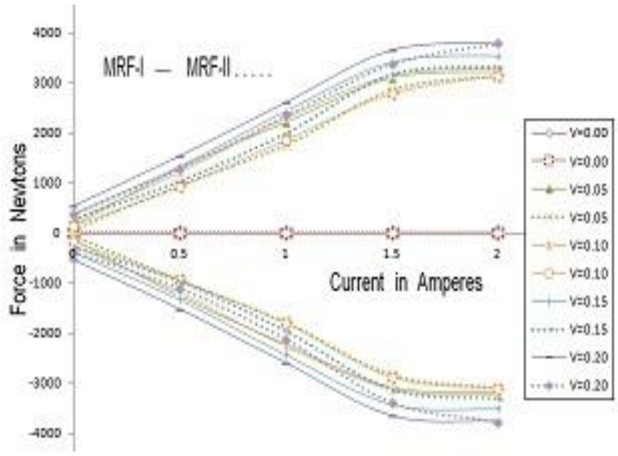

Figure 8. Variation of Force (F) wrt Current (I)

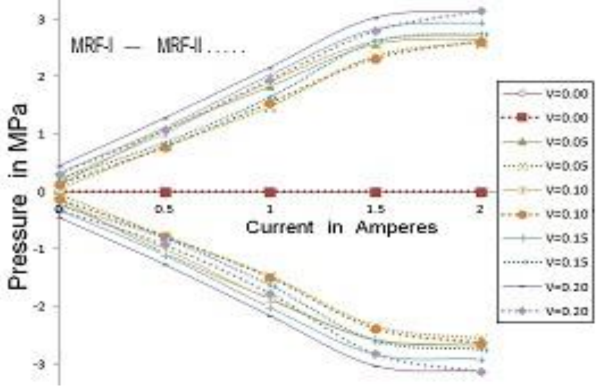

Figure 9. Variation of Pressure (P) wrt Current (I)

ii) The slope of the plot, for all velocities, does not rise at an input current value of 1.5A for both MRF-1 and MRF-2. Hence, almost saturation of magnetic particles is observed. Upon increasing the current beyond 2A the magnetic particles may be completely saturated and offer maximum resistance to external stimuli.

V. CONCLUSIONS

In this work, a fundamental understanding of the behavior of two Magneto-rheological (MR) fluids has been developed through the synthesis and characterization. The findings of the study are listed below:

i) Larger damping forces are seen at higher velocities in all the cases for a constant value of input current.

ii) The resistive force (F) of the MR damper is less dependent upon velocity (Vp) for all the curves and is much dependent upon the input current (I).

iii) The damper resisting force (F) purely depends upon its piston velocity (Vp) when no input current (I) is applied.

iv) Almost saturation point for the input current of 1.5A is observed in case of MRF-1 andMRF-2.

v) Larger damping force is observed with MRF-1 for all values of constant input current levels when compared to MRF-2. This is due to the high concentration of magnetic particles.

vi) The resistance provided by MRF-1 in all the cases was always found to be higher than MRF-2. This is due to different concentrations of magnetic particles in both the fluids with MRF-1 being more viscous than MRF-2.

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REFERENCES

1. P. Phulé (2001), Magnetorheological (MR) fluids: principles and applications, Smart Materials Bulletin 2001/2 pp. 7-10.
2. S.T. Lim, M.S. Cho, I.B. Jang, H.J. Choi (2004), Magneto rheological characterization of carbonyl iron based suspension stabilized by fumed silica, Journal of Magnetism and Magnetic Materials, Vol. 282, pp.170-173.
3. G. Bossis, E. Lemaire (1991), Yield stresses in magnetic suspensions, Journal of Rheology, Vol.35 pp.1345-1354.
4. H. Pu, F. Jiang, Z. Yang, (2006), Preparation and properties of soft magnetic particles based on Fe3O4 and hollow polystyrene microsphere composite, Materials Chemistry and Physics, Vol.100 pp.10-14.
5. M. Kciuk, R. Turczyn (2006), Properties and application of magneto rheological fluids, Journal of Achievements in Materials and Manufacturing Engineering, Vol.18, pp.127-130.
6. S.P. Rwei, H.Y. Lee, S.D. Yoo, L.Y. Wang, J.G. Lin (2005), Magnetorheological characteristics of aqueous suspensions that contain Fe3O4 nanoparticles, Colloid Polymer Science, Vol.283, pp.1253-258.
7. C. Holm, J.J. Weis (2005), The structure of ferrofluids: A status report, Current Opinion in Colloid and Interface Science, Vol.10, pp.133-140.
8. http://www.mecheng.adelaide.edu.au/avc/publications/public/2006/preprint_a06_030.pdf
9. L.M. Jansen, S.J Dyke (2000), Semi-active control strategies for MR dampers: comparative study, Journal of Engineering Mechanics, American Society of Civil Engineers, Vol.126, pp. 795-802.
10. S.P. Rwei, H.Y. Lee, S.D. Yoo, L.Y. Wang, J.G. Lin (2005), Magneto rheological characteristics of aqueous suspensions that contain Fe3O4 nanoparticles, Colloid Polymer Science, Vol.283, pp. 1253-1258.
11. T. Pranoto, K. Nagaya (2005), Development on 2DOF-type and Rotary-type shock absorber damper using MRF and their efficiencies, Journal of Materials Processing Technology, Vol.161, pp.146-150.
12. R. Turczyn, M. Kciuk (2008), Preparation and study of model megnetorheological fluids, Journal of Achievements in Materials and Manufacturing Engineering, Vol.27/2 pp.131-134.
13. J. Huang, J.Q. Zhang, Y. Yang, Y.Q. Wei (2002), Analysis and design of a cylindrical magnetorheological fluid break, Journal of Materials Processing Technology Vol.129 pp.559-562.
14. K. Dhirendra, V.K. Jain, V. Raghuram (2004), Parametric study of magnetic abrasive finishing process, Journal of Materials Processing Technology, Vol149, pp. 22-29.
15. K. Shimada, Y. Wu, Y. Matsuo, K. Yamamoto (2005), Float polishing technique using new tool consisting of micro magnetic clusters, Journal of Materials Processing Technology Vol.162-163, pp.690-695.
16. Bica (2004), Magnetorheological suspension electromagnetic brake, Journal of Magnetism and Magnetic Materials, Vol.270, pp.321-326.