

Experimental Study of Magnetorheological and Sedimentation Properties of Carbonyl Iron Based Damping Fluids

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ABSTRACT: In the recent years, semiactive damping systems have gained importance in vibration reduction applications. Damping is achieved by using magnetorheological fluids used which contains magnetizable ferrous particles as main ingredient along with other additives. Damping effect depends upon these ingredients and the type of base oil used. The objective of this study was to investigate the magnetorheological and sedimentation properties of carbonyl iron based damping fluids with fumed silica as an additive. Damping effects of fluids with different proportions of additives were studied by applying external magnetic field. Sedimentation and stability properties were also evaluated. Damping fluids were prepared using silicone oil and paraffin oil as bases and mixing carbonyl iron powder in different proportions. Fumed silica was also added to study stability and sedimentation. Damping effect of each fluid was studied by investigating changes in the dynamic viscosity. Damping fluids have varied applications including structural vibrations and provide semiactive vibration control. Appropriately prepared fluids enhance the durability and exhibits excellent properties. This study aims to provide guidelines for preparation of durable damping fluids with excellent damping effects.

KEYWORDS: Magnetorheological fluids, Carbonyl iron (CI) powder, Magnetorheological properties, Semiactive damping, Sedimentation in fluids, Vibration control.

I. INTRODUCTION

Damping fluids also commonly known as magnetorheological fluids are the colloidal suspensions which can change from liquid to quasi-solid phase under the influence of external magnetic. Small sized, magnetizable, ferrous particles contained in the low permeability oil constitute a damping fluid. When subjected to an external magnetic field, these particles are attracted to each other and form chain like and columnar structures in the direction of applied magnetic field and the phase changes from liquid to solid as shown in Fig. 1. When the external field is removed, the phase again changes to liquid. [1-2]. The quick response, good reversibility and controllable performance of such fluids make them suitable for use in various devices for structural vibration control applications [3-5].

Damping fluids are essentially the colloidal suspensions containing ferrous, magnetizable particles of average 3 to 5 μm size [6-7] like, iron and its nitrides, carbides, carbonyl iron, low carbon steel, silicon steel etc. in a suitable carrier fluid such as water, vegetable oil, ethylene glycol, silicone oil, or any mineral, synthetic oil. The carrier fluid serves as a dispersed medium and ensures homogeneity of particles [8].

II. MATERIALS AND METHODS

The function of a carrier liquid is to provide a base for suspension of magnetizable particles. The carrier fluid should possess certain properties such as non-reactive nature towards magnetic particles, components and devices in which it is used; appropriate boiling temperature; vapor pressure at elevated temperatures and freezing point. Considering these factors, for the preparation of damping fluids, two types of colorless carrier liquids having different viscosity were selected; viz. Paraffin oil with viscosity 50 mPa.s and silicone oil with viscosity 300 mPa.s.

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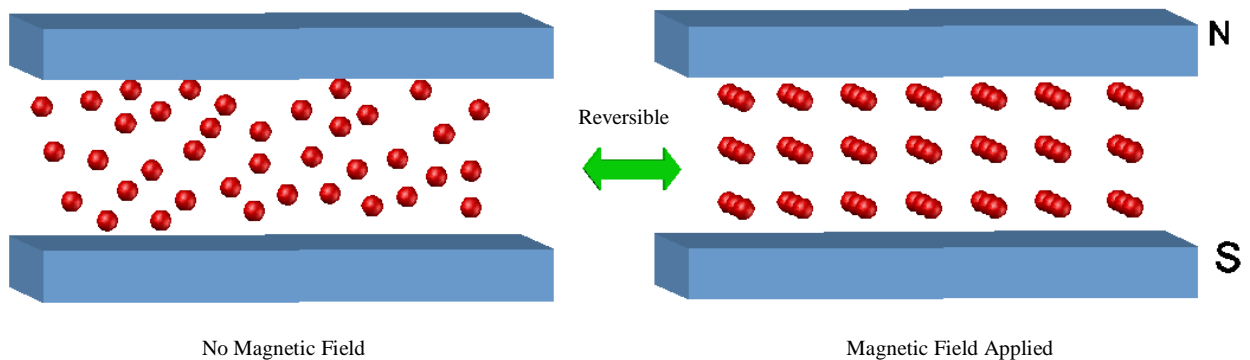


Fig. 1 Behavior of the damping fluid under magnetic field

Carbonyl iron powder having high purity and super electromagnetic properties was selected as magnetizable particles and added to the carrier liquids. The powder is having uniform microscopic spheres with average size of 3 μ and apparent density 7.87g/cm³. Earlier studies have shown that 30% to 40 % concentration of magnetizable particles produced better results. Hence, for studying the magnetorheological properties and also the sedimentation and stability study, the concentration of carbonyl particles was fixed as 30% and 40% of the total weight of fluid. Fumed silica powder (Aerosil 200) was also added as stabilizing agent. The damping fluids were prepared by mixing the appropriate quantities of base oil, CI powder and Aerosil and then continuously stirring with a mechanical stirrer.

Compositions used for preparing the damping fluids are as listed in the Table 1.

Table 1: Compositions of investigated damping fluids

Base oil	CI powder content [wt. %]	Additive	
		Type	Amount [wt. % of CI]
Paraffin Oil 50 mPa.s	30	Fumed Silica (Aerosil 200)	0
			1
			2
Paraffin Oil 50 mPa.s	40	Fumed Silica (Aerosil 200)	0
			1
			2
Silicone oil 300 mPa.s	30	Fumed Silica (Aerosil 200)	0
			1
			2
Silicone oil 300 mPa.s	40	Fumed Silica (Aerosil 200)	0
			1
			2

III. EXPERIMENTAL WORK

The sedimentation experiment was conducted by placing the samples of the prepared damping fluids in cylindrical glass tubes with markings for level measurement. The samples were observed for 35hrs. at regular intervals. The sedimentation was measured by visual observation of the position changes of boundary between clear and turbid part of carrier oil. As a result sedimentation ratio was calculated using the formula stated in equation (1). Sedimentation ratio, S , is defined as a proportion between length of clear and turbid part of MR fluid in the glass tube at a particular observed time.

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Fig. 2 Damping fluids placed in cylindrical glass tubes.

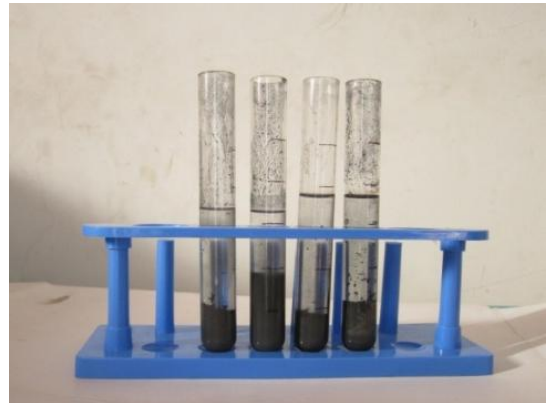


Fig. 3 Different levels of clear and turbid part observed after specific time.

$$S = \frac{y}{x+y} \quad (1)$$

where, x is the length of the clear part, and y is the length of the turbid part.

Magnetorheological properties of the damping fluids were investigated using Brookfield (DV-E) Viscometer as shown in Fig. 4 and Fig. 5. Dynamic viscosity can be measured by viscometer. Permanent magnets of high gauss power were used to apply external magnetic field. By changing the distance between the magnets, the magnetic flux density changed. The changes in the flux densities were measured with the help of probe of Gauss meter. The readings were conducted at different rpms of the spindle and values of dynamic viscosity for particular magnetic fields were noted.



Fig. 4 Brookfield Viscometer apparatus.

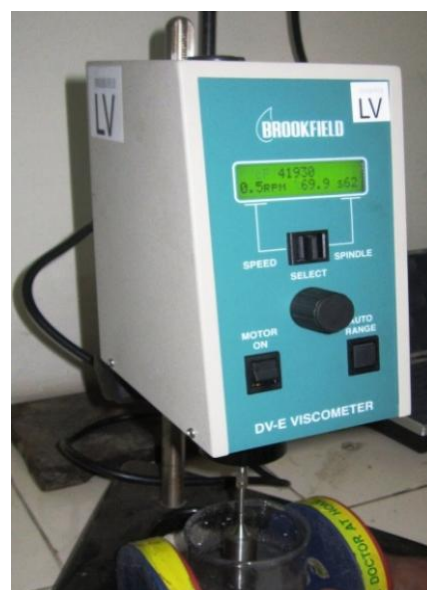


Fig. 5 Application of magnetic field using permanent magnets

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IV. RESULTS AND DISCUSSIONS

It was noticed that stability of investigated fluids improves after adding the stabilizer. This is the effect of the fumed silica, which prevents agglomeration of the carbonyl iron particles. Fumed silica particles tend to cling to each other as close as possible in order to minimize the free energy of the surface. Thus, a randomly distributed grid of solid forms

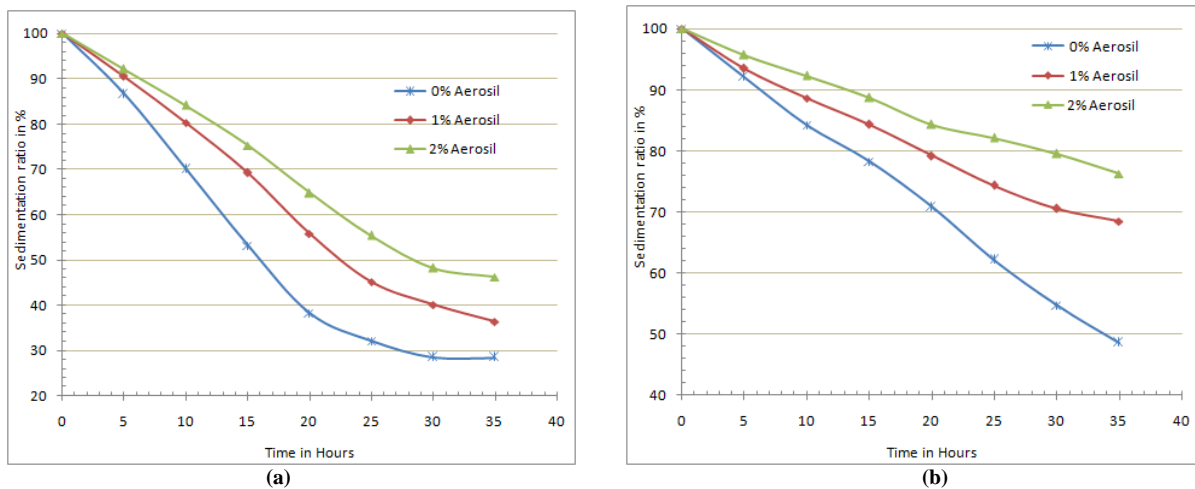


Fig. 6 Effect of stabilizer on sedimentation of (a) Paraffin Oil and (b) Silicone Oil

inside the fluid medium. This three-dimensional structure exhibits viscoelastic properties resulting in enhanced viscosity and pronounced yield values. Sedimentation is inhibited, because the solid particles are no longer free to move downwards in the gravitational field. It was observed that the value of the sedimentation coefficient was larger than 20% for the stabilized fluid (for 2% aerosil) as compared with unstabilized fluid as shown in Fig. 6. The value of the sedimentation coefficient contained in the range 78- 95% after 35 hrs. for the damping fluid with higher initial viscosity.

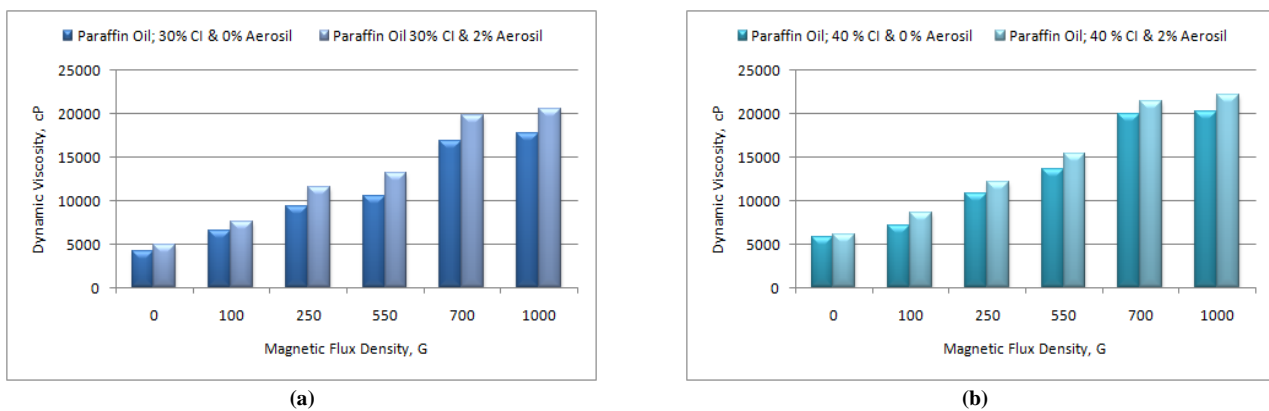


Fig. 7 Effect of CI concentration and stabilizer on dynamic viscosity for Paraffin oil with (a) 30% CI and (b) 40% CI

As shown in Fig. 7 (a) and (b), with the increase in CI powder percentage, and increased stabilizer quantity, the dynamic viscosity of the paraffin based oil was increased.

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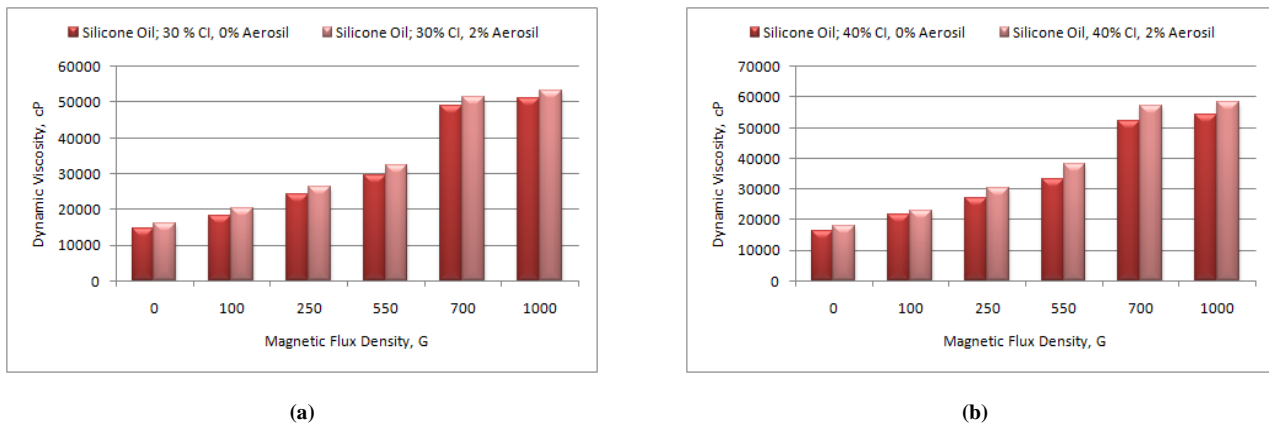


Fig. 8 Effect of CI concentration and stabilizer on dynamic viscosity for Silicone oil with (a) 30% CI and (b) 40% CI

Similarly, with the increase in percentage of CI powder, the resistance to flow increased for the silicone based oil, which increased the viscosity of the fluid. Under the influence of external magnetic field, the shear stress increased as shown in Fig. 8.

V. CONCLUSION

On the basis of conducted investigations following conclusions were formulated:

1. With the increase of carbonyl iron particles concentration, the viscosity of the damping fluids increased for both Paraffin and Silicone oils.
2. Added Aerosil (fumed silica) in 2% with relation to CI amount further inhibited sedimentation of the carbonyl iron particles especially effective for high loaded (40 %) damping fluid.
3. The dynamic viscosity of investigated damping fluids increased in the response to presence of an external magnetic field due to the thickening and thixotropy.

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