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Effect of Volume Fraction of Carbonyl Iron Powder on Rheological Properties in Magnetorheological Fluids

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Abstract: Four kinds of magnetorheological fluids (MRFs) with 10%, 20%, 30% and 40% of carbonyl iron powder were prepared respectively. The stability of magnetorheological fluid was measured by natural sedimentation observation method. The zero - field viscosity and shear stress of the four sets of MRFs were analyzed and their shear properties were analyzed. The results show that sedimentation rate of MRFs decreases and needs more time to reach a stable value with the increase of volume fraction of carbonyl iron powder. With the increase of the volume fraction of MRFs, the number of ferromagnetic particles dispersed in the base fluid increased, the inter-particle spacing decreased, the attraction force increased, the viscosity of MRFs increased, the range was 2.8Pa ▪ s ~ 25Pa ▪ s. With the increase of magnetic field, the shear stress of MRFs increases significantly, ranging from 200Pa to 49kPa. Magnetic field is constant, the shear stress first shows an upward trend and then reaches a stable value with the increase of shear rate. The larger the volume fraction of carbonyl iron powder is, the greater the shear stress is.

Keywords: magnetorheological fluid, shear stress, zero field viscosity, sedimentation rate

1. INTRODUCTION

Magnetorheological fluids are suspended in a mixture of tiny soft magnetic particles, non-permeable liquids and surfactants with high permeability [1]. The rheological properties of magnetorheological fluids change rapidly under the action of external magnetic field, and its basic characteristic is that it is a Newtonian fluid when there is no magnetic field, and its structure and performance change greatly under the applied magnetic field Rheology, mechanics and magnetism, etc.), can be in the thousandth of a second from the liquid into a solid state, showing the behavior of Binhan plastic body, with a certain shear yield stress [2]. Under the applied magnetic field, the soft magnetic particles in the magnetorheological fluid are arranged in a chain-like structure in the direction of the magnetic field, resulting in an increase in the viscosity of the fluid, from the liquid to a solid; after the magnetic field is removed, the soft magnetic particles are The structure returned to the original disorder state, and finally returned to the liquid state [3]. As the applied magnetic field gradually increases, the shear stress increases. The use of magnetorheological fluid shear stress from the magnetic field can control the characteristics of a variety of intelligent devices can be manufactured, widely used in braking, vibration, polishing and clutch, etc. [4].

The performance analysis of magnetorheological fluid has been the hotspot of domestic and foreign scholars, Bompos [5] and so on the application of magnetorheological fluid in the transmission device has been analyzed to get the advantages of magnetorheological fluid in the transmission device; [6] and other effects of different additives on the performance of magnetorheological fluid, found that the additive composition and measurement of different magnetorheological fluid shear stress changes; Iglesias [7] and other dynamic properties of the magnetorheological fluid carried out The results show that the magnetorheological fluid changes under dynamic shear force. Wang Xiqi [8] and so on to prepare an oleic acid-coated carbonyl iron powder as a ferromagnetic material, the magnetic field of the magnetic field of the zero-field viscosity and shear stress and conventional prepared magnetic rheological properties of different. In this study, the magnetic fraction was 10%, 20%, 30% and 40%, respectively, using carbonyl iron powder as ferromagnetic particles and dimethyl silicone oil as carrier liquid and lauric acid as surface active agent. The effect of different volume fraction of carbonyl iron powder on the rheological properties of magnetorheological fluids was studied.

2. PREPARATION OF MR FLUID

2.1 Preparation of raw materials

The magnetorheological fluids used in this experiment are self-developed. Because the material properties of magnetic particles are one of the important factors that affect the rheological properties of magnetorheological fluids, this experiment adopts high magnetic saturation intensity, high magnetic permeability and low Magnetic coercivity of carbonyl iron powder as a suspension phase material, the carbonyl iron powder used in the average particle size of about 3. 3mm, purity of about 97. 8% (Jiangsu Tianyi Micro-powder Co., Ltd. production). Dimethyl silicone oil as a continuous phase carrier liquid, lauric acid as a surfactant, lauric acid and dimethyl silicone oil are from the National Pharmaceutical Group Chemical Reagent Co., Ltd., which dimethyl silicone oil model H201, viscosity 25cSt. All reagents were subjected to any pretreatment and used directly in the preparation of magnetorheological fluids. The mass fraction of carbon montene powder was 10%, 20%, 30% and 40%, respectively. The mass fraction of surfactant was 2% of carbonyl iron powder, 10% 20%, 30% and 40% respectively.

2.2 Preparation process

The preparation process of the magnetorheological fluid is as follows: The raw material is weighed according to the electronic balance of model HZT-A + 200, and the carbonyl iron powder and lauric acid are put into the stainless steel ball mill of model KQM-X4 planetary ball mill After stirring, the grinding balls were sintered at a speed of 100 r • min-1 for 2 h to uniformly coat the lauric acid on the surface of the carbonyl iron powder. Then, dimethyl silicone oil was added to the ball mill, After mixing with glass rods, continue grinding at 300 r • min-1 for 1 h. The mixture was taken out and placed in a DZF-6020 vacuum oven and vacuumed at room temperature for 10 min to obtain a magnetorheological fluid. A magnetic rheological fluid sample with 10%, 20%, 30% and 40% volume fraction of carbonyl iron powder was prepared. Figure 1 is a volume fraction of 10% of the magnetorheological fluid samples.

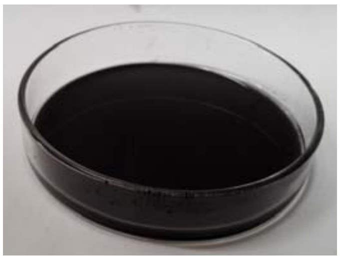


Fig.1 Samples of MRFs

3. EXPERIMENTS

3.1 Sedimentation stability

In this experiment, the natural sedimentation observation method is used to measure the stability of the magnetorheological fluid [9-10]. The observation principle is intuitive and clear. The method is easy to implement and the result is close to the practical effect. The sedimentation rate is the sedimentation rate W, and the sedimentation rate is expressed as follows

$$W = a/\left(a+b\right)\times 100\% \qquad (1)$$

Where: a is the height of the supernatant after precipitation of the magnetorheological fluid, and b is the height of the thickened portion of the lower layer after precipitation. First, from the preparation of four samples of each of the 5 ml of liquid were placed in four cylinders, respectively, the volume of each volume in the volume of magnetic fluid fractions, the cylinder placed on the level of work platform, every 24 h observed 1 settlement And the supernatant height a was measured respectively, and the sedimentation rate of magnetorheological fluid was obtained.

3.2 Rheological properties

In this experiment, the Antonfield Physica MCR 301 plate test rheometer was used to measure the zero field viscosity and shear stress of magnetorheological fluids. In the course of the test, the magnetorheological fluid was placed between the upper and lower plates, the diameter of 20mm, in order to prevent the magnetorheological fluid in the test process of the climbing effect, the edge of the plate with a protective ring. Unlike conventional rheometers, the plate rheometer can apply a magnetic field during the test and the sample is placed in a relatively uniform magnetic field environment by means of a magnetic field generating attachment (Physica MRD 180). The accessory generates a uniform magnetic field through a current-controlled built-in coil and applies the magnetic field to the sample via the magnetron skeleton to form a closed magnetic circuit system that measures the zero-field viscosity and shear of the different volume fraction of the magnetorheological fluid Stress changes.

4. RESULTS AND DISCUSSION

4.1 Sedimentation stability

Magnetorheological fluid sedimentation rate changes with time as shown in Figure 2, it can be seen from the figure, the magnetotelluric fluid settling rate began to slow growth, followed by a similar linear increase, and then gradually stabilized. The larger the volume fraction of the carbonyl iron powder, the longer the time required for the settling rate to reach a steady value, and the smaller the sedimentation rate when the MR fluid stabilizes. Such as the volume fraction of 30% of the magnetorheological fluid, before 80h, the sedimentation rate growth is slow, and then nearly linear growth, at 320h, the settlement rate reached a stable, the value of 9.8%.

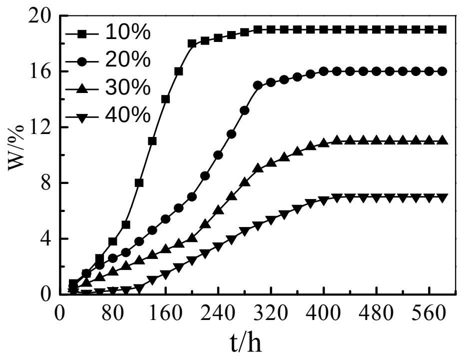


Fig. 2 Sedimentation rate of MRFs

The magnetostatic fluid in the magnetorheological fluid begins to decrease with the increase of time, and then decreases gradually and finally stabilizes, which is mainly due to the fact that the magnetorheological fluid is still in the process of standing, the interaction between the ferromagnetic particles is relatively large, the interaction force is weak and the particles precipitate. With the increase of precipitation, the particle volume ratio in the precipitated layer increases and the interaction force between the ferromagnetic particles increases, Until a relatively balanced state is reached without settling again. The higher the volume fraction of the carbonyl iron powder particles, the lower the sedimentation rate of the magnetorheological fluid, the mechanism of which is the effect of the interaction between the particles. The force of the ferromagnetic particles in the carrier fluid is very complex, such as gravity, buoyancy and viscous resistance of the carrier fluid, surface tension, collision between particles, and the presence of weak magnetic interaction between the particles. In these forces, the gravitational force causes the particles to descend, and the buoyancy and viscous drags hinder the sedimentation. Therefore, the increase of the volume fraction of the carbonyl iron powder particles causes the average distance between the particles to be shortened, so the interaction is strengthened, When the repulsive force is equal, the particles no longer settle, the magnetorheological fluid reaches equilibrium and the sedimentation rate becomes smaller.

4.2 Zero field viscosity

The zero-field viscosity of the magnetorheological fluid varies with the shear rate. As shown in Fig. 3, it can be seen that the zero-field viscosity of the magnetorheological fluid decreases as the shear rate increases; the same shear rate , The change of the field viscosity increases with the increase of the volume fraction of the carbonyl iron powder, and the change of the zero field viscosity is 2.8Pa ▪ s ~ 25Pa ▪ s. The zero-field viscosity of the magnetorheological fluid increases with the increase of the volume fraction of the carbonyl iron powder. The mechanism is that the magnetorheological fluid increases its internal friction because of the presence of the ferromagnetic particles. The viscosity of the liquid becomes large. With the increase of the volume fraction of the ferromagnetic particles, the number of magnetic particles dispersed in the base liquid is increased, the particle spacing is reduced, the attraction between the ferromagnetic particles increases, and the internal friction increases in the unit volume, resulting in the magnetorheological fluid The zero field viscosity also becomes larger.

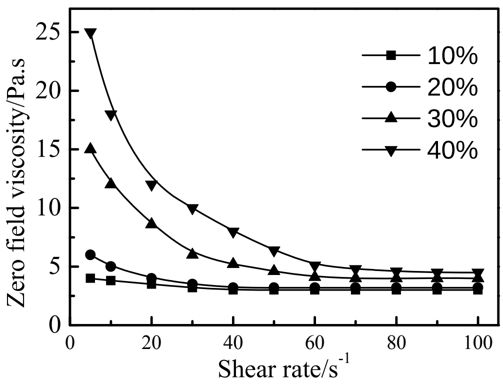


Fig. 3 Zero field viscosity of MRFs

4.3 Shear stress

When the shear rate is 300s-1, the relationship between the shear stress and the magnetic field of the magnetorheological fluid is shown in Fig. 4. It can be seen from the figure that the shear stress of the magnetorheological fluid increases significantly with the increase of the magnetic field, And finally the stability value is reached. When the magnetic induction intensity of the magnetic field is constant, the larger the volume fraction of the carbonyl iron powder is, the larger the shear stress of the magnetorheological fluid is in the range of 200Pa ~ 49kPa.

When the magnetic induction intensity is small, the ferromagnetic particles in the magnetorheological fluid are in the magnetized state, and the particles are aggregated to form a columnar structure, resulting in a significant increase in the shear stress of the magnetorheological fluid. With the continuous increase of the magnetic induction intensity, the ferrite particles formed in the magnetorheological fluid gradually reach the saturation, resulting in a steady increase in the shear stress of the magnetorheological fluid and gradually reaching a stable value. The larger the volume fraction of the carbonyl iron powder in the magnetorheological fluid, the more the columnar structure formed in the unit volume, and the greater the shear stress of the magnetorheological fluid.

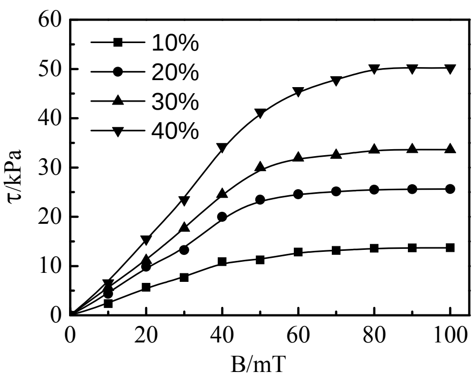
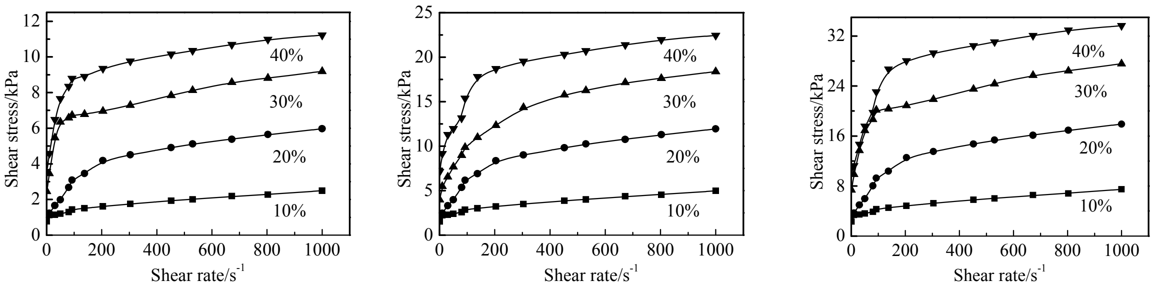


Fig. 4 Dependence of shear stress on magnetic field

The change of shear stress of magnetorheological fluid with different magnetic induction is shown in Fig. 5. It can be seen from Fig. 6 that under the same magnetic field, with the increase of shear rate, the stress increases at the beginning and reaches a steady value after 200 s-1. When the magnetic induction intensity is 20mT, 40mT and 60mT, the shear stress of magnetorheological fluid with different volume fraction increases obviously, and the growth is approximately multiplied. The ferromagnetic particles in the magnetorheological fluid show a columnar structure under the action of the magnetic field. When the shear is applied, the columnar structure is continuously broken and the shear stress is increased. With the increase of the shear rate, the fracture will be re-formed at the same time into a new particle column. When the fracture and recombination reach equilibrium, the shear stress reaches a steady value.



(a)B=20mT (b)B=40mT (c)B=60mT

Fig.5 Dependence of shear stress on shear rate under different magnetic fields

5. CONCLUSION

The larger the volume fraction of the carbonyl iron powder in the magnetorheological fluid, the smaller the sedimentation rate of the magnetorheological fluid, the longer the time required for the settling rate to reach the stable value, the higher the stability of the sedimentation rate, the higher the volume fraction of 40% Rheological fluid, sedimentation rate of 6%. The zero field viscosity increases with the increase of the volume fraction, and the variation range is 2.8Pa ▪ s ~ 25Pa ▪ s. With the increase of magnetic field, the shear stress of magnetorheological fluid increases obviously, then gradually reaches the steady value, and the shear stress range is 200Pa ~ 49kPa. When the magnetic field is constant, the shear stress increases with the increase of the shear rate, and then increases with the increase of the shear rate. The larger the volume fraction of the magnetorheological fluid increases and the shear stress increases.

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