Shear Performances of Magnetorheological Fluids

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Abstract

Magnetorheological Fluids (MRFs) were prepared with silicon oil and carbonyl iron powder. The shear stress and apparent viscosity of the MRFs were measured by the rheometer under different volume fraction of carbonyl iron powder, and the volume ratio of carbonyl iron powder was 40%, 30%, 20%, 10% respectively. The experimental results show that the shear stress of MRFs increase slowly but the apparent viscosity decrease exponentially with the increase of the shear rate under the same volume ratio. Shear stress increases obviously when the volume ratio is more than 20%, and the volume ratio increases from 10% to 20%, the growth of shear stress becomes smaller. The shear rate of the shoulder slope is between 100s^{-1} and 300s^{-1}, and the decrease of the apparent viscosity is the most.

Keywords

Magnetorheological Fluids, Shear Stress, Shear Rate, Apparent Viscosities.

1. Introduction

In intelligent materials, Magnetorheological Fluids (MRFs) have been widely valued for their particular magnetic rheological effects [1]. MRFs are a kind of suspension which is composed of micron sized magnetic particles and non magnetic liquid (mineral oil, silicon oil, etc.) [2-3]. Rheological properties of MRFs change in the presence of magnetic field. It reveals non-Newton rheological behavior without magnetic field. Its microscopic structure and macroscopic mechanical behavior will change significantly and has a certain shear yield stress in the external magnetic field [4]. MRFs have the advantages of controllable, rapid and reversible, which is widely used in the fields of vehicle, building structure, medical equipment, sports equipment, polishing and sealing of precision materials [5-6].

Preparation method, microstructure and mechanical properties of MRFs have been a key problem in the research hotspot is widely used to solve, for domestic and foreign scholars have done a lot of research. Kim [7] study on the shear stress of the MRFs and proposes a double viscosity model, the model of magnetorheological fluid shear stress and magnetic field intensity is proportional to the microstructure and mechanical properties; Bossis [8] investigated the yield stress of MRFs and found the dependence of yield stress and magnetic field; Sternberg [9] based on the shear stress of MRFs increases with the increase of the applied current, the magnetorheological fluid damper is designed, which is applied to the vibration reduction of high rise building. There is an exponential relationship between shear stress and magnetic field when MRFs are shearing. In this paper, the rheological behaviors of MRFs are investigated experimentally. The variations of apparent viscosity and shear stress of MRFs under volume ratio are studied.

2. Experiments

2.1 Preparation of MRFs.

With carbonyl iron powder as raw materials, MRFs were prepared by volume ratio of carbonyl iron powder was 40%, 30%, 20%, 10% respectively. Carbonyl iron powder and dimethyl silicon oil were weighted based on calculation. Carbonyl iron powder came from Jiangsu Tianyi Super Fine Metal Powder Co. Ltd. The average size of carbonyl iron powder is 3.5μm. The viscosity of dimethyl silicon oil (Ji'nan Duoweiqiao Chemical Co. Ltd) is 25cst. Surface active agents was also produced by Ji'nan Duoweiqiao Chemical Co. Ltd.

The preparation method of MRFs were prepared by the traditional method [10], and the preparation process flow chart was shown in Figure 1.

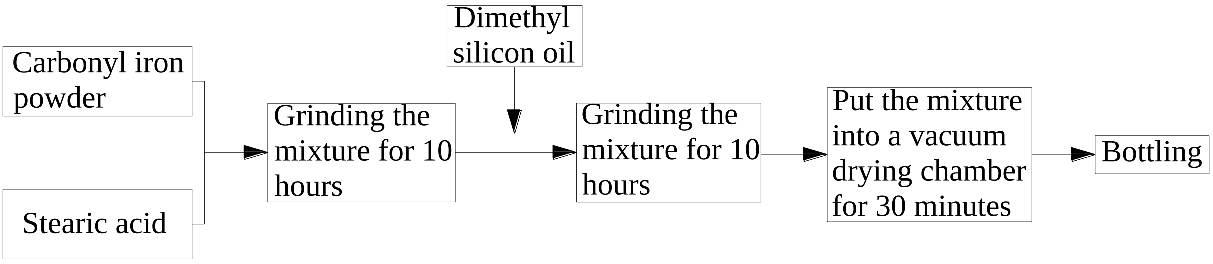

Fig.1 Preparation process of the MRF

2.2 Shear stress test.

Rheometer physical MCR301 was used to test the prepared MRFs. As shown in Figure 2, MCR301 is composed of two coaxial equal radius disks, the bottom one is fixed and the toasting one is coupled to the rotor through a shaft. Between the two mentioned disks, there is a gap that filled with MRFs. The values of stress and strain can be acquired by testing the torque and angular velocity of the rotor.

MRFs was dripped between the upper and lower plates, shear rate was set in the range of 0~1000s-1, external current was set to 1A, temperature was set to 18 ℃, the shearing time was 30s, sampling once per 1s. The shear stress and apparent viscosity of the MRFs were measured by the rheometer physical MCR301under different volume fraction of carbonyl iron powder, and the volume ratio of carbonyl iron powder was 40% , 30%, 20%, 10% respectively.

Fig.2 Rheometer Physical MCR 301

3. Results and Discussion

With the appearance of the volume ratio, the dependence of shear stress on shear rate is shown in Figure 3. Shear stress began to increase steady and then reached a stable value with the increase of shear rate at the same volume ratio. The larger the volume ratio is, the larger the shear stress is. Shear stress increases significantly with the increase of volume ratio at the same shear rate. Shear stress increases obviously when the volume ratio is more than 20%, and the volume ratio increases from 10% to 20%, the growth of shear stress becomes smaller. The range of shear stress is 6Pa~18.16kPa. The dependence of apparent viscosity on shear rate is shown in Figure 4. Apparent viscosity decreases with the increase of shear rate, and decreases with the increase of volume ratio. Apparent viscosity decreases significantly in the range of $100s^{-1}$~$300s^{-1}$ with the increase of shear rate.

When the volume ratio of carbonyl iron powder is small, the number of magnetic particles dispersed in the carrier liquid is few, and particle spacing is large. With the volume ratio of carbonyl iron powder increased, the number of magnetic particles dispersed in the carrier liquid increased, particle spacing decreases, the attraction between ferromagnetic particles increases, the viscosity and resistance of MRFs increases, and the shear yield stress increases.

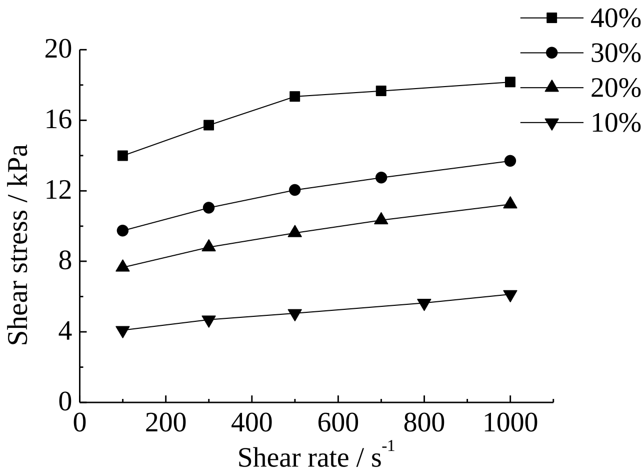

Fig. 3 Dependence of shear stress on shear rate

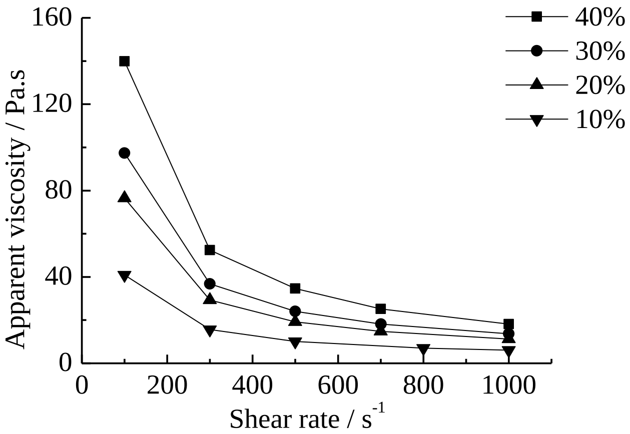

Fig. 4 Dependence of apparent viscosity on shear rate

4. Conclusion

The shear stress of MRFs increases slowly but the apparent viscosity decreases exponentially with the increase of the shear rate under the same volume fraction.

The shear stress of MRFs increases with the increase of the shear rate and the volume ratio of carbonyl iron powder, and shear stress and volume ratio of carbonyl iron powder tend to be linear relationship. Shear stress increases obviously when the volume ratio is more than 20%, and the volume ratio increases from 10% to 20%, the growth of shear stress becomes smaller. The apparent viscosity of MRFs decreases with the increase of the shear rate, and then tends to be stable, and increases with the increase of the volume fraction of carbonyl iron powder. Apparent viscosity decreases significantly in the range of $100s^{-1}$~$300s^{-1}$ with the increase of shear rate.

Acknowledgements

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References

[1] K. Karakoc, P.J. Edward, A. Suleman. Design considerations for an automotive magnetorheological brake, Mechatronics, vol. 18(2008), 434-447.

[2] S.M. Fayyad. Experimental Investigation of Using MR Fluids in Automobiles Suspension Systems, Research Journal of Applied Sciences & Engineering and Technology, vol. 22(2010), 25-38.
[3] F.Imaduddin, S.A.Mazlan, H.Zamzuri. A design and modelling review of rotary magnetorheological damper, Materials and Design, vol. 51(2013), 54-60.
[4] C.J. Yi. Magnetic rheological liquid: preparation, performance testing and constitutive model (Chongqing University Press, China 2011) p. 20-30.
[5] B. Ioan, Y.D. Liu, H. J. Choi. Physical characteristics of magnetorheological suspensions and their applications, Journal of Industrial and Engineering Chemistry, vol. 19(2013), 394-406.
[6] J.S. Weng, H.Y. Hu, M.K. Zhang. Rheological mechanical properties test and modeling, Chinese Journal of Applied Mechanics of magnetorheological fluid, vol. 03(2000), 1-5+140.
[7] KIM P, LEE J I, SEOK J, Analysis of a viscoplastic flow with field-dependent yield stress and wall slip boundary conditions for a magnetorheological (MR) fluid [J]. Journal of Non-Newtonian Fluid Mechanics, 2014, 204(1) : 72-86.
[8] G. Bossis, P. Khuzir, S. Lacis, et al. Yield behavior of magnetorheological suspensions, J. J. Magn. Magn. Mater. 258-259(2003)456 -458.
[9] STERNBERG A, ZEMP R, LLERA J C. Multiphysics behavior of a magneto-rheological damper and experimental validation [J]. Engineering Structures, 2014, 69:194–205.
[10] JING Wanquan, ZHU hong, GONG Xinglong. A magnetic current change liquid stability: CN101457172 [P]. 2009-06-17.