Performances of Magnetorheological Fluids during Shear Processes

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Abstract

MRFs were prepared with silicon oil and carbonyl iron powder, and the volume fraction of carbonyl iron powder was 40%.Rheometer Physical MCR 301 was used to measure the shear stress of the MRFs. The experimental results show that shear stress was 12kPa when no shear load was applied and the shear stress increases rapidly to 32.5 kPa at the beginning of shearing. During the rest process of shear rate varied from 500 s-1 to 0s-1, the varying velocity of shear stress in slower than that of raising process. The value of shear stress remain at 23.43kPa at the end of the experiment, instead of 12kPa at the beginning.

Keywords

magnetorheological fluids, shear stress, shear rate.

1. Introduction

Magnetorheological fluids(MRFs) belongs to the controllable fluid is composed of tiny, soft magnetic particles with high permeability and low hysteresis and non- magnetic liquid mixture of suspension [1-2]. Because the flow of magnetorheological fluid under magnetic field and is instantaneous and reversible, the deformation of the shear yield strength and the strength of the magnetic field has a stable corresponding relationship, so it is a kind of widely used, the excellent performance of the current smart material, magneto rheological fluid is widely used in disc brake and clutch.

Shear performances of magnetorheological fluids(MRFs) depend on many parameters, such as shear rate, magnetic field, etc [3,4]. The shear stresses of MRFs were studied with varying shear rate processes in this paper.

2. Experiments

2.1 Preparation of MRFs

The preparation method of MRFwas prepared by the traditional method [5], and the preparation process flow chart was shown in Fig. 1. To test the stability of magnetorheological fluid samples after prepared by natural subsidence observation method [6], through static observation and measurement of 15 days, found that the configuration of the MRF sedimentation rate was 10%, and no hardening phenomenon, experimental samples qualified, meet the requirements.

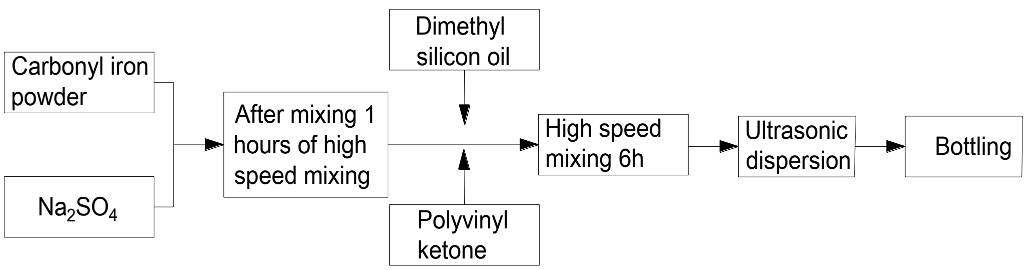
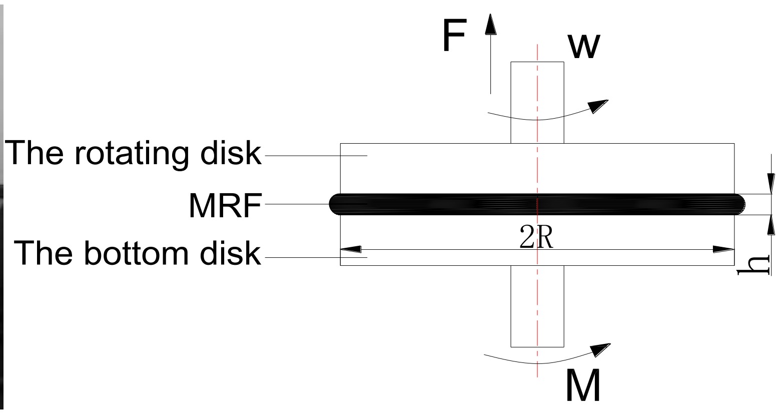


Fig.1 Preparation process of the MRF

2.2 Shear stress test

Rheometer physica MCR301 is used to test the prepared MRFs. As shown in Fig. 2, MCR301 is composed of two coaxial equal radius disks, the bottom one is fixed and the toating one is coupled to the rotor through a shaft [7]. 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 were prepared with silicon oil and carbonyl iron powder, and the volume fraction of carbonyl iron powder was 40%. Rheometer Physica MCR 301 was used to measure the shear stress of the MRFs. The excitation current of the rheometer was set to 2A. In rhe first 10s, no shear load was applied, then the shear rate was raised to the next 10s, at last the shear rate was decreased down to 0s-1 with the same velocity [8].



(a) Rheometer Physical MCR 301 (b) Working principle diagram

Fig.2 The structure of Rheometer Anton Paar Physical MCR 301

3. Results and Discussion

The dependence of shear stress on a varying shear rate is shown in Fig. 3. Shear stress was11kPa when no shear load was applied. The shear stress increase rapidly to 31kPa at the beginning of shearing. During the rest process of shear rate raising, the shear stress only increased 3.2%. During the decreasing process of shear rate varied from 500 to 0s, the varying velocity of shear stress is slower than that of raising process. The value of shear stress remain at 23.43kPa at the end of the experiment, instead of 11kPa at the beginning.

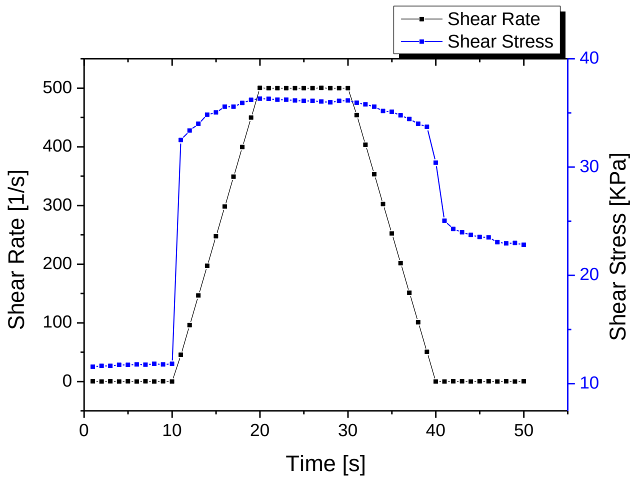


Fig.3 Dependence of shear stress on a varying shear rate

In 0s-10s of test process, adjust the MRF shear rate to the 0s-1 level for 10s. In the 20s and 30s of the test process, adjust the MRF shear rate to the 500s-1 level for 10s. In the 40s and 50s experimental testing process, adjust the MRF shear rate to the 0s-1 level for 10s. Test and record three experimental MRF shear stress changes.

According to MRF shear stress change curve which can be seen in Fig. 4, volume ratio of 40% of MRF, the excitation current of 2A, when the shear rate of 0, the MRF shear stress value of 12 kPa; In the 20s and 30s experiment process, although the MRF shear rate remains the same, but the shear stress at a particular numerical floating up and down, maximum fluctuation is 1.6%; In the 40s and 50s in the process of the experiment, when the shear rate is kept at 0, the shear stress is gradually reduced from 25 kPa to 23.43 kPa instead of the initial 12 kPa., this is because the shear process changed the apparent viscosity of MRF, and apparent viscosity of the liquid is not unable to recover quickly.

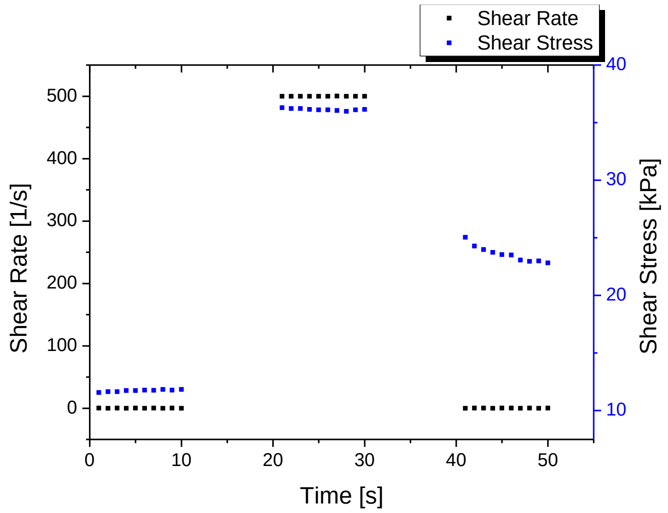


Fig.4 Shear stress when shear rate is constant

In 10s-20s of the test process, adjust the MRF shear rate, the linear increase by 50s-1 to 500s-1, maintain 10s; In the 30s to 40s in the process of test, linear decrease rheometer the rotor speed, make MRF shear rate from the 500s-1 to reduce to 50s-1, test and record the whole experiment of MRF shear stress in the process of change.

According to MRF shear stress change curve which can be seen in Fig. 5, volume ratio of 40% of MRF, the exciting current is 2A, when the MRF shear rate increases from 50s-1 to 500s-1, the shear stress increases slowly from 33kPa to 37.5kPa. When the MRF shear rate decreases from 500s-1 to 50s-1, the shear stress decreases slowly from 37kPa to 33.5kPa. Two segments in the process of shear rate and shear stress to maintain symmetry.

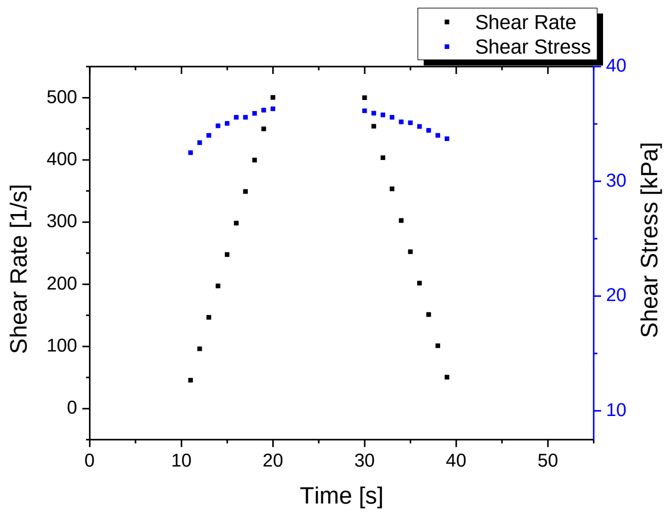


Fig.5 Shear stress when shearing rate is linearly changed

4. Conclusion

The dependence of shear stress on a varying shear rate is shown in Fig 3. Shear stress was 12kPa when no shear load was applied. The shear stress increases rapidly to 32.5 kPa at the beginning of shearing. During the rest process of shear rate varied from 500 s-1 to 0s-1, the varying velocity of shear stress in slower than that of raising process. The value of shear stress remain at 23.43kPa at the end of the experiment, instead of 12kPa at the beginning.

Acknowledgements

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References

[1] H.See. Field dependence of the response of a magnetorheological suspension under steady shear flow and squeezing flow, J. Rheol. Acta. 42(2003)86-92.
[2] A. Sternberg, R. Zemp, J.C. Llera . Multiphysics behavior of a magneto-rheological damper and experimental validation, J. Eng. Struct. 69(2014)194–205.
[3] Lagger HG, Breinlinger T, Korvink JG, Moseler M, Di Renzo A, Di Maio F & Bierwisch C (2015) Influence of hydrodynamic drag model on shear stress in the simulation of magnetorheological fluids. Journal of Non-Newtonian Fluid Mechanics 218: 16-26.
[4] Guo CW and Chen F(2014) Yield shear stress model of magnetorheological fluids based on exponential distribution. Journal of Magnetism and Magnetic Materials 360(6): 174-177.
[5] JING Wanquan, ZHU hong, GONG Xinglong. A magnetic current change liquid stability：CN101457172[P]. 2009-06-17.
[6] WU Jirong, LI Xiaoqi, LI Xuehui, etal. Preparation of the matneto-rheological fluid and experimental study on its surface tension coefficient[J]. Micronanoelectronic Technology. 2014, 51(3): 145-150.
[7] K. Wollny, J. Lauger, Siegfried Huck. Magneto sweep - a new method for characterizing the viscoslastic behavior of magneto-rheological fluids, Applied Rheology, 12(1), 2013, 394-407.
[8] Ioan Bica, Y.D. Liu, H.J. Choi. Physical characteristics of magnetorheological suspensions and their applications, Journal of Industrial and Engineering Chemistry, 19(4), 2013, 394-407.