Experimental study on shear properties of magnetorheological fluids

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Abstract

The magnetorheological fluid of carbonyl iron powder with different volume fraction was prepared and tested under rheometer. The effects of shear rate, magnetic field strength and volume ratio on shear properties of magnetorheological fluids were investigated by experimental results. When the shear rate is variable, the shear stress increases rapidly and the shear stress increases slowly at the initial stage of shear. When the magnetic field intensity is variable, the shear stress of magnetorheological fluid increases rapidly with the increase of current. With the further increase of current, the growth of shear stress slows down. When the volume ratio is variable, the shear stress of magnetorheological fluid has a linear relationship with volume ratio. The shear stress increases rapidly between the 20%-30% volume ratio.

Keywords

Magnetorheological fluid, shear rate, magnetic field intensity, shear stress.

1. Introduction

With the development of society and science and technologymore and more projects have put forward new challenges to traditional technology and materials. As a new type of material, magnetorheological fluid (MRF) has emerged as the times require. Magnetorheological fluid (MRF) is a suspension liquid, which is formed by suspension of many fine magnetic particles in the carrier liquid[1]. The magnetorheological fluid has a magnetorheological effect[2]. The magnetorheological effect means that when the magnetic field is applied to the magnetorheological fluid, the magnetorheological fluid will quickly change from the liquid into a solid, and the change process is controllable and reversible. Because of its excellent material properties, magnetorheological fluid (MRF) has been successfully applied to[3-4], such as building and bridge engineering, and has long-term practical significance.

In the present study, Bossis[5] and others have prepared a magnetorheological fluid with a volume fraction of 40%. The yield stress is analyzed. The results show that there is an exponential increase between the shear yield force and the magnetic induction intensity. Yao Jun[6] and others studied the effect of different iron content on the shear strength of magnetorheological fluid, and found that the higher the content of iron, the greater the shear strength.

2. Composition and preparation of magnetorheological fluid

In order to study the shear properties of magnetorheological fluids, it is necessary to discuss the effect of different factors on the shear stress. Magnetorheological fluid is composed of ferromagnetic particles, carrier fluid and additives. Common ferromagnetic particles include iron, cobalt, nickel and other particles. The liquid includes silicone oil, synthetic oil, water and so on. The additive is a molecular layer attached to the surface of ferromagnetic particles, which can effectively organize the settlement of magnetorheological fluid[7-8].

In order to meet the requirements of experiments, magnetorheological fluids with volume ratios of 10%, 20%, 30% and 40% were prepared. In the process of preparation, the carbonyl iron powder is mixed with the additive at high speed to dry, and then two methyl silicone oil is added to the ball mill for several hours, and the magnetorheological fluid is prepared.

3. Analysis of experimental results

Because ferromagnetic particles form chain like structures in the direction of magnetic field, the shear stress is the force perpendicular to the magnetic field required to cut off the chain structure. In order to explore the effect of shear rate, magnetic field strength and volume ratio on shear yield stress, the 10%, 20%, 30%, 40% volume ratio of magnetorheological fluids were put into a rheometer. The experimental results were as follows.

In order to explore the effect of magnetorheological fluid on shear stress under different shear rates, the magnetorheological fluid with 40% volume ratio was tested under the current of 3A. As is shown in picture 1. It is found that shear stress is 35.84Pa when shear rate is 0. The shear rate is 0.05s-1, and the shear stress increases to 26.22kPa immediately. As the shear rate further increases to 700s-1, the shear stress increases slowly from 42.18kPa to 45.67kPa. It can be seen that at the initial stage of shear, the shear rate has great influence on the shear properties of magnetorheological fluids, and has little influence in the middle and later stages.

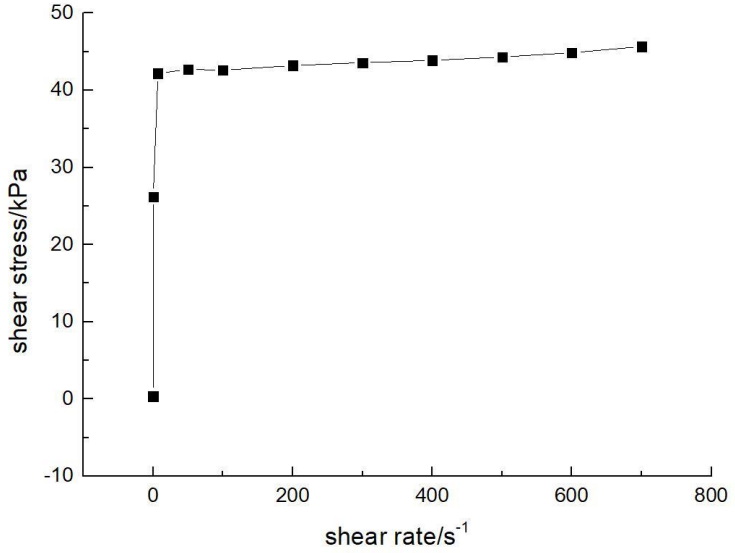

Fig.1 the curve of shear rate and shear stress

In order to explore the effect of different magnetic field intensity on the shear properties of magnetorheological fluids, the magnetorheological fluid with 40% volume ratio was tested at the shear rate of 700s-1. As is shown in picture 2. Since the magnetic field in the rheometer is realized by the current, high current means a high magnetic field, so in the experiment the current is replaced by a magnetic field as a variable, from 0A to 4A. It can be seen that when the current is 0.1A, the shear stress of magnetorheological fluid is 1.301kPa. When the current increases to 2A, the shear stress increases rapidly to 39.84kPa. Then the current increases to 4A, and the shear stress of magnetorheological fluid increases to 54.05kPa. When the current increases at 0-2A, the shear stress will be greatly affected. When the current is at 2A-4A, the shear stress is less affected.

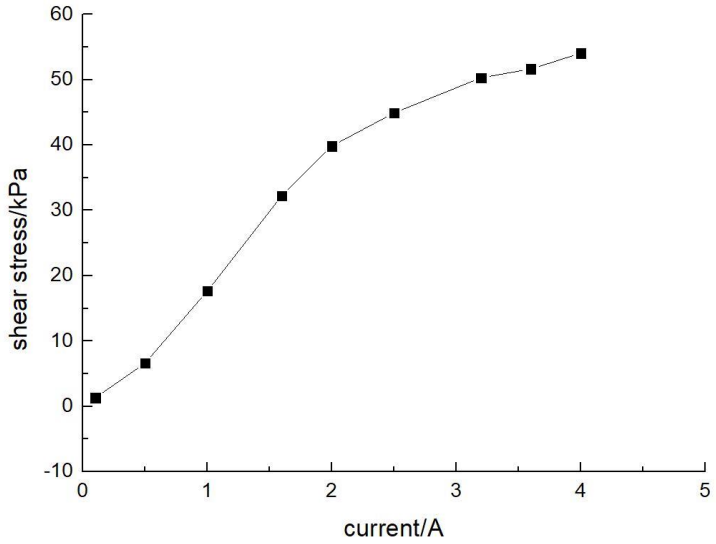

Fig.2 the curve of current-shear stresss

In order to investigate the effect of magnetorheological fluids on the shear properties of different volume fraction ratios, the magnetorheological fluids with 10%, 20%, 30% and 40% volume ratios were tested with the 3A current and the 700s-1 shear rate. As is shown in picture 3. It is found that when the volume ratio is 10%, the shear stress of magnetorheological fluid is 13.26kPa. When the volume ratio increased to 40%, the shear stress of magnetorheological fluid increased to 45.91kPa and increased by about 2.5 times. When the volume fraction is 20%-30%, the shear stress increases more rapidly.

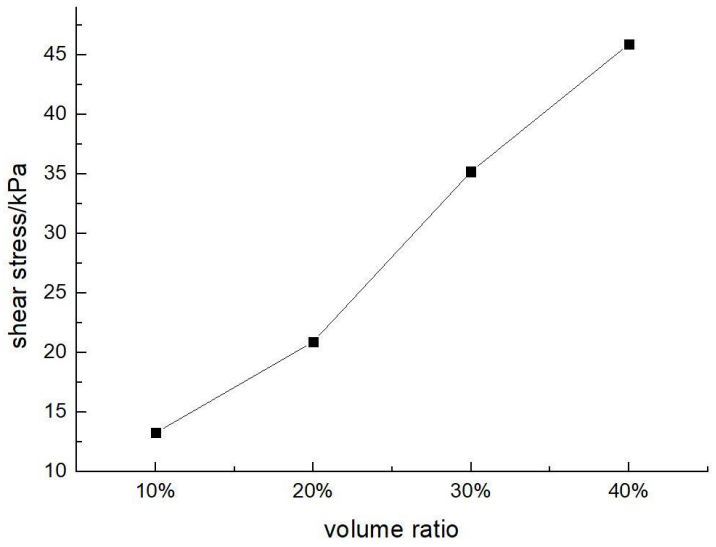

Fig.3 the curve of volume ratio-shear stress

Based on the above experiments, the following conclusions are drawn. The increase of shear rate, magnetic field strength and volume ratio will increase the shear stress of magnetorheological fluid. When the shear rate is variable, the shear stress increases rapidly and the shear stress increases slowly at the initial stage of shear. When the magnetic field intensity is variable, the shear stress of magnetorheological fluid increases rapidly with the increase of current. With the further increase of current, the growth of shear stress slows down. This is because when the magnetic field increases, the magnetic particles in the magnetorheological fluid quickly gather into the chain in the direction of the magnetic field, and the greater the intensity of the magnetic field, the greater the shear yield stress. Since the number of magnetic particles in magnetorheological fluid is limited, the effect of magnetic field strength on the shear stress will be smaller even if the magnetic field strength increases further.

When the volume ratio is variable, the shear stress of magnetorheological fluid has a linear relationship with volume ratio. The shear stress increases rapidly between the 20%-30% volume ratio. This is because with the increase of volume ratio, the concentration of magnetic particles in magnetorheological fluid increases and the number of particles increases. Under the same magnetic field, the higher the volume ratio, the more chain structure the magnetorheological fluid formed. Accordingly, the shear stress will increase as well.

4. Conclusion

The magnetorheological fluid of carbonyl iron powder with different volume fraction was prepared and tested under rheometer. The effects of shear rate, magnetic field strength and volume ratio on shear properties of magnetorheological fluids were investigated by experimental results. It is found that the shear stress, magnetic field strength and volume ratio increase the shear stress of magnetorheological fluid. When the shear rate is variable, the shear stress increases rapidly and the shear stress increases slowly at the initial stage of shear. When the magnetic field intensity is variable, the shear stress of magnetorheological fluid increases rapidly with the increase of current. With the further increase of current, the growth of shear stress slows down. When the volume ratio is variable, the shear stress of magnetorheological fluid has a linear relationship with volume ratio. The shear stress increases rapidly between the 20%-30% volume ratio.

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