World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

Rheological Effect of Magnetorheological Fluid

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Abstract: MRF can flow freely in the absence of a magnetic field. After the magnetic field is applied, the ferromagnetic particles rapidly assemble into chains under the action of a magnetic field, and the MRF shear stress rapidly increases to become a solid, and the apparent viscosity of the solid is large. The change is reversible and controllable. The change of the viscosity, plasticity and other parameters of the MRF with the change of the magnetic field is called the magnetorheological effect of the MRF.
Keywords: Magnetorheological fluid, solid-like, magnetorheological effect.

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1. INTRODUCTION

Liquid viscous transmission is a new type of fluid transmission. It utilizes the shear action of the oil film between friction pairs to transmit power, and achieves stepless speed regulation by changing the thickness of oil film [1]. Magnetorheological fluid is a new type of magnetic smart material, which is a black opaque suspension formed by micron-sized soft magnetic particles uniformly dispersed in carrier liquid and dispersant [2-3]. Magnetic particles are the most important components of magnetorheological fluids. Under the action of a magnetic field, polarized magnetic particles change from a random distribution to a chain arrangement, resulting in a magnetorheological effect. Spherical granular magnetic particles with high magnetic saturation strength, high magnetic permeability, low coercivity, and diameter of 1~10μm can make the magnetorheological fluid have better magnetorheological properties.

2. EXPERIMENTS

MRF has a good magnetorheological effect, which shows that under the action of a magnetic field, MRF changes from a free-flowing state to a solid-like state. To observe the macroscopic manifestations of the rheological effects of MRF, the prepared MRFs were poured into A, B, and C culture dishes, respectively, in which the bottom of the culture dish A had no round permanent magnets (no magnetic field). A 21 mm thick book (medium intensity magnetic field) was placed between the circular permanent magnets. The culture dish C was placed directly on

a round permanent magnet (strong magnetic field). The state of MRF in the three petri dishes was observed. As shown in Fig. 1 , the ferromagnetic particles were uniformly dispersed in the carrier liquid under the action of the non-exciting magnetic field, the MRF rapidly gathered into the chain along the direction of the magnetic field under the medium-intensity magnetic field. Obvious observation of the dense chains in the carrier fluid, continue to increase the magnetic field strength, MRF particle chains become cylindrical, showing a semi-solid state, the maximum shear yield stress.

(a) No magnetic field (b) Medium magnetic field (c) Strong magnetic field

Fig.1 Macro-phenomena of MRF rheological effect

In order to better observe the magnetorheological effect of MRF, a microscope experiment bench as shown in Fig. 2 was built to observe the poly-chain process and particle chain structure of MRF under the magnetic field. The test bench is composed of an ultra-deep depth 3D high-speed microscope, an industrial control machine, an electromagnet, and an adjustable voltage source, wherein the electromagnet can control the size of the magnetic field by adjusting the voltage source size. The magnification of the microscope is adjustable. The microscope displays the observed two-dimensional or three-dimensional image on the industrial computer. The industrial computer can measure and edit the image.

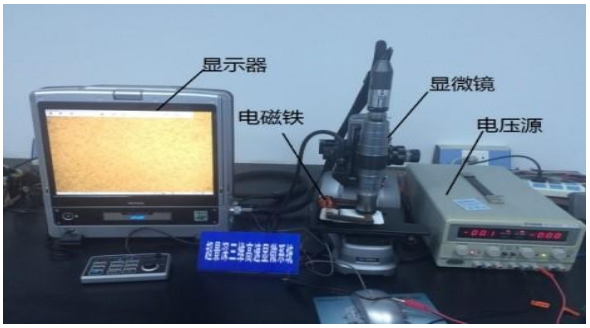
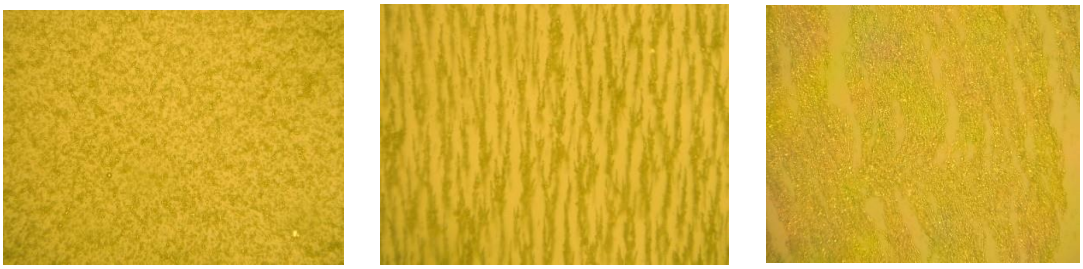


Fig.2 Fig of 3D high speed microscope system

Use a glass rod to remove a small amount of MRF sample with a volume ratio of 1%. Apply the sample to the microscope slide and adjust the appropriate magnification until a clear chain of particles is observed on the display. Adjust the voltage source, control the size of the magnetic field, observe and record changes in the particle chain [4]. The observation results are shown in Fig. 3. When the voltage source is zero, that is, when there is no external magnetic field, the ferromagnetic particles rapidly gather into the chain along the direction of the magnetic field, and the particle chains interdigitate with each other. Under the blocking of the particle chain,

the MRF no longer flows. When the magnetic field is removed, the chain breaks under the flow of the carrier fluid, but due to the presence of remanence magnetization of the ferromagnetic particles, the particles attract each other to agglomerate and flow with the dimethyl silicone oil.



(a) MRF state when no magnetic field is applied (b) 50ms after applying magnetic field to MRF state (c)Remove the applied magnetic field 50ms after the MRF state

Fig.3 Chain forming process image of MRF(Enlarge 500 times)

3. DISCUSSION

In view of the excellent rheological properties of magnetorheological fluids, they have been more and more widely used in industries and equipment such as automotive, construction, medical, fitness equipment, and military vehicle suspension systems [5-6]. Application forms include servo valves, shock absorbers, dampers, brakes, and clutches. Magnetorheological transmission is a specific application of magneto-rheological effect in the field of engineering transmission. It uses magneto-rheological fluid as the working medium, transmits power through the shear stress of the magnetorheological fluid between transmission interfaces, and continuously changes by controlling the external strength. Shear stress, so as to achieve stepless adjustment of transmission torque and speed, with rapid response, reversible, simple control and low energy consumption, strong anti-interference ability [7-8], in the mechanical and electrical equipment soft start, soft braking, no Speed regulation and overload protection have wide application prospects.

The magnetorheological transmission device is a kind of power transmission equipment that uses magnetorheological fluid as a transmission medium, and the stepless adjustment of the transmission torque is achieved by changing the size of the applied magnetic field. Due to the slippage between the transmission components, the magnetorheological transmission device will generate a large amount of heat during the operation process, causing the temperature of the magnetorheological fluid to rise. The viscosity of the magnetorheological fluid will be greatly affected by the temperature, and the viscosity will change. The change of shear stress will affect the chain formation of the material under the magnetic field, resulting in the decrease of the magnetorheological effect and the uncontrollable change of the shear force.

4. CONCLUSION

It can be seen from the macroscopic and microscopic observation results of the MRF magnetorheological effect that the MRF will form a chain structure along the direction of the

excitation magnetic field under the action of a magnetic field, and the polymer chain response time is in the order of milliseconds, resulting in an instantaneous increase in the apparent viscosity. The fluid's Newtonian fluid becomes a solid. After the magnetic field has receded, it returns to a free-flowing state and shows good reversible controllability.

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