Delay time of magnetorheological fluids in porous foam metal

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Magnetorheological (MR) dampers can be controlled effectively by magnetic fields. Under the external magnetic fields, MR fluid behaves as a non-Newtonian fluid with controllable viscosity. The response time is a critical factors to determine its performance. A new MR damper by using foam metal to store MR fluids is proposed. However, the response time is a little different with the traditional ones for the time to extract the MR fluid from metal foam. Therefore, in this paper, the delay time, MR fluid was drawn out from the porous metal foam, was investigated in terms of the internal structure formation by a precise control of external magnetic fields.

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1. Introduction

As a smart kind of materials, the properties of magnetorheological fluid (MR) can be controlled by an external magnetic field. Under the effect of the applied magnetic fields, the MR fluids abruptly transformed within milliseconds from fluid-like to solid-like state by showing changes of rheological properties of MR fluids such as yield stress and an enhancement of viscosity [1, 2]. Since its first report on MR effect, there have been numerous reports [1] on MR characteristics and its effects in real applications [3].

Over past decades, many researches focus on the MR damper for vibration applications [4]. The traditional MR damper is usually designed to be filled with MR fluids in working cylinder. Compared with the passive damper, one key barrier to widespread commercial application of the device is the relative higher cost. Therefore, Calson [5] introduced a sponge around the piston of the damper, Liu [6] have proved the feasibility to use porous foam metal to store MR fluid instead of sponge, Yao [7] proposed a new metal foam MR damper and its response time was studied. The normal force of MR fluids in metal foam were also studied [8-10]. However, since the filled with MR fluids of metal foam, compared with traditional MR damper, the response time is a little longer for the delay time drawn out from the metal foam. It is important to further research on this delay time to the other device design by using the metal foam. Therefore, this paper experimentally this time MR fluids delay in porous metal foam and analyses its principle in terms of the internal structure formation by a precise control of external magnetic fields

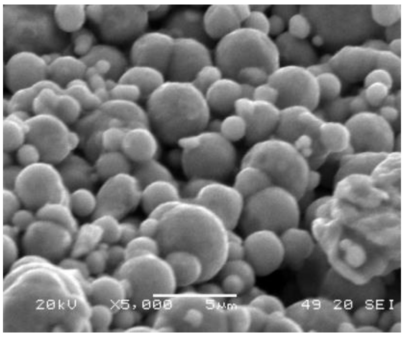
2. Experiment setup and methods

2.1 Materials

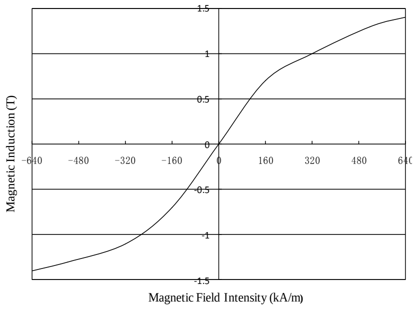
The viscosity of the specimen MR fluid at zero magnetic field is 0.8 Pa.s, and the iron particle diameter is 3.6 μm. The magnetic characteristics are depicted in Fig. 1. The thickness is 2mm, and the other parameters are shown in Table 1, which is the same as Yao [7].

Table 1. Properties of nickel foam metal

Permeability	Density (g/cm^3)	Pore size (PPI)	Porosity (%)
1.5	0.26	110	85



(a) Particle size distributions of samples

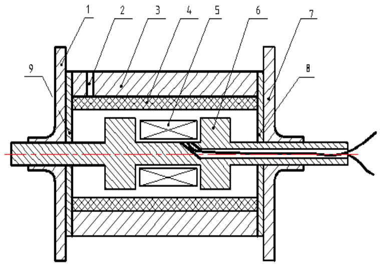


(b) B-H curve

Fig. 1. Characteristic of MR fluids

2.2 Porous foam MR fluid damper

The new porous foam metal MR damper is described in Fig. 2.



1,7 End cap of cylinder Piston rod; 2 Gap; 3 Cylinder; 4 Porous foam nickel; 5 Coil; 6 Piston; 8,9 Bronze

Fig. 2. Porous foam metal MR damper

The metal foam is adhered on the surface of the inner working house. The dimension can be obtained by the ratio in Tab2. When the extern magnetic field strength is zero, MR fluids are stored in porous foam, none of MR fluids appearances in shear gap, once the current is on, MR fluid stored in the pore of porous foams will be extracted and begin to fill the shear gap, in the action of magnetic field, the MR effect will be produced, and the damping force is changed.

Table 2. Main parameters of the foam damper

Maximum Stroke(mm)	+60
Number Of coils	1
Turns of coil	1635
Shear gap (mm)	1
Diameter of cylinder(mm)	44
Effective length of piston (mm)	90

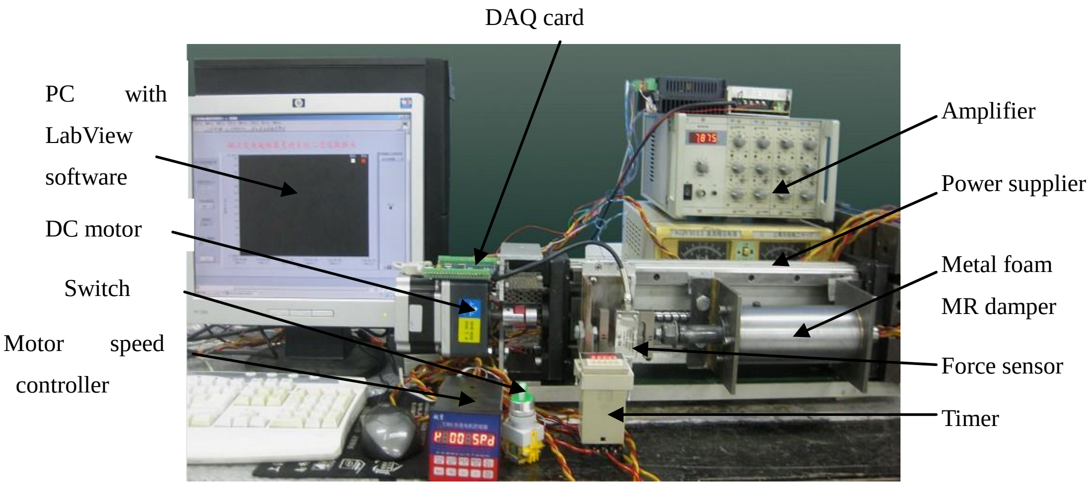


Fig. 3. Test rig of foam MR damper

2.3 Experiment set-up

The entire experiment rig is shown in Fig. 3. The foam metal MR damper was fixed on the linear rail, one piston rod which was driven by a steady state-adjustable DC motor is fasten to a force sensor. It is driven with a DC motor (model: YJ01) whose speed can be adjusted by a controller with a speed encoder. A force sensor with an amplifier was used to measure the damper force delivered through the foam MR damper. The coil was activated by the power supply. The test signals in the system are gathered by a DAQ data acquisition, the data process and display are done by PC with Labview software. A timer was designed to synchronize the start of the magnetic field application and the measurement starting point. The strength of the magnetic field can be adjusted by changing the current that flows through the coil.

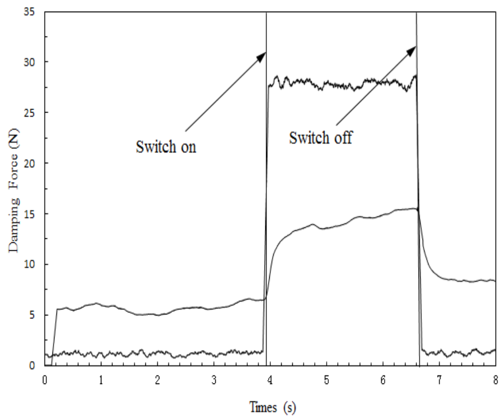


Fig. 4. Damper force vs. time

Compared with the response time in Yao [6], the delay time each is tested in this paper with changing the metal foam in MR damper. Therefore, it can exactly reflect the time MR fluids firstly be extracted from the metal foam.

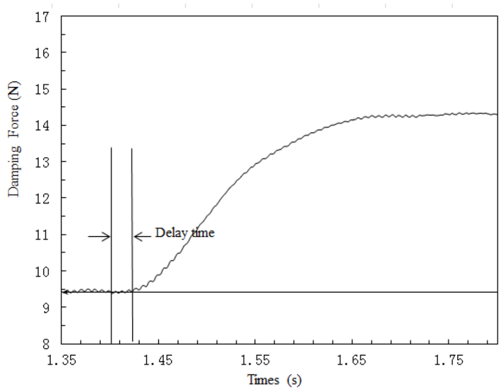


Fig. 5. Method to find the delay time

The methods to do the experiment are as following: the delay time is the time period from current on to damper force signal detected (during which MR fluids are drawn out from metal foam to shear gap), which can be seen in Fig. 4 and Fig. 5.

3. Experiment results and discussion

The delay time, which the MR fluids stored in porous of foam metal are drawn out to shear gap, have been measured as a function of magnetic field strength that was controlled with the change of current. The current was supplied to the coil by the magnetic field generator.

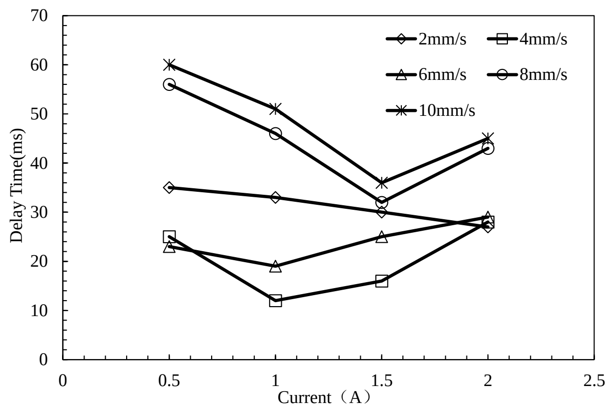


Fig. 6. Changes of delay time of porous foam metal MR damper as a function of current at different shear velocity

Interestingly, Fig. 6 contains novel change of delay time at each fixed shear velocity condition. We could find the two distinct flow regions.

In the beginning stage, the viscosities decreased (region I), as soon as it decreased to the lowest point, it finally showed the abrupt increase with the increase of magnetic field strength (region II).

In the first part (region I), the internal structure formed by magnetic field might be less dominant, following the usual energy dissipation mechanism at a fixed shear rate. But the increase of magnetic field starts to generate fibril chain structure, which is shorter than the gap distance between two parallel plates. This kind of short chain structure might be the reason of such temporal shear thinning. Finally, above a critical magnetic field (region II), with the incorporation of shear flow, the generated longer fibril chains collided with each other and formed more robust columnar structure, which can span the gap, resulting in the holding of rotating upper plate. In this region, the characteristic flow behavior follows the previous studies, such as the increase of stress with magnetic field. In addition, the CI only system with a filled symbol, which exactly coincided with sub particle added system, demonstrated that its flow properties are being maintained.

4. Conclusions

This paper examined novel features of the submicron-sized particle filled CI-MR fluid by precisely controlling magnetic field strength, especially under weak magnetic field strength; a temporal decrease of shear viscosity in sweeping magnetic field strength. We explained this abnormal behavior in conjunction with the structure development by magnetic particles: formation and destruction of gap-spanning chains by magnetic field under the steady shear flow.

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