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Magnetic field simulation and analysis of a metal foam MR fluid damper

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In the paper, the magnetic field distribution and the influence of some parameters of a metal foam magnetorheological (MR) fluid damper, including excitation current and gap width are investigated. Metal foam (MR) fluid damper owns some advantages, such as long lifetime and low cost. In order to analyze the effect of excitation current and gap width on magnetic induction intensity, a series of simulations of dampers in different currents and gaps is conducted in the ANSYS FEM software. From the simulation results, the conclusion indicates that excitation current and gap width are two key factors for the damper, with the increasing of excitation current, magnetic induction intensity in the gap increases, once the current is above 1.5A, the increment of magnetic induction intensity is not obvious longer, and the magnetic induction intensity increases with the decreasing of gap width.

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Keywords: Metal foam, Magnetorheological fluid damper, Magnetic field simulation, Magnetic induction intensity

1. Introduction

Magneto-rheological (MR) fluids, typically composed of micron-sized magnetic particles, carrying liquid and additives, are a kind of smart materials [1]. In the absence of external magnetic field, MR fluids behave as free-flowing liquid state, and in the presence of external magnetic field, MR fluids have the rheological property [2], which could transfer to a semi-solid state of chain-like structures in a few milliseconds. What's more, the transition is reversible [3]. Considering the characteristics and properties of MR fluids, it is feasible to make significant application on the vehicles, engineering structures and other fields.

However, as for traditional MR fluid damper, the relatively high cost and short lifetime are two key factors to limit much wider application, and the reasons leading to high cost including special sealing devices, surfacing finishing of the moving piston and precision mechanical tolerances. A novel MR fluid damper with the idea of using a porous sponge to contain MR fluids is proposed by Carlson [4]. No sealing devices are needed in the damper. However, the sponge MR fluid damper also has some shortcomings, such as, in order to ensure enough amounts of MR fluids, the relatively large thickness of sponge is required, leading to the low magnetic field strength. In addition, the low intensity of the porous sponge will make a short lifetime. Considering the shortcomings of the porous sponge MR fluid damper, Liu [5] introduced the feasibility of using metal foams to store MR fluids, then Liu and Yao [6] proposed a new kind of MR fluid damper with the idea of using the metal foam to store MR fluids. The damper reduces the cost, and the lifetime is extended because of the larger strength of metal foam.

In this paper, the magnetic field distribution of the metal foam MR fluid damper, and the influence of some parameters on the damper are investigated. The magnetic field distribution is acquired by the electromagnetic analysis of magnetic field in the damper through ANSYS v13.0 Workbench. On the basis of a series of simulation analysis, the relationships between the magnetic induction intensity and mentioned parameters are investigated.

2. Metal foam MR fluid damper

As a sample, metal foam Ni is selected to store MR fluids. The structure diagram and a photograph of the damper are shown in Fig. 1 and Fig. 2. The damper is composed of working cylinder, piston with piston rod, coil and metal foam Ni filled with MR fluids. Metal foam Ni, 2mm in thickness, is adhered to the interior surface of magnetic working cylinder, and the number of turns is 1635. No sealing structure is needed in the structure, thus it reduces the degree of wear and tear. Meanwhile, it lessens the amount of MR fluids, then, it decreases the cost. The metal foam MR fluid damper has a variety of advantages including good abrasion resistance, fine output damping force controllability, long service life and so on. Some basic parameters of the metal foam MR fluid damper are shown in Table1.The unit in Table 1 is *mm*.

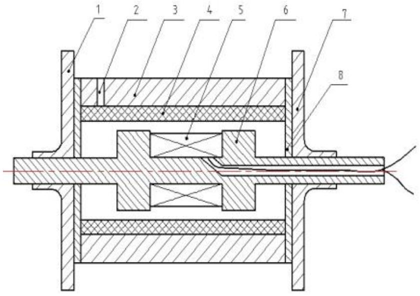


Fig. 1. Structure diagram of the damper.

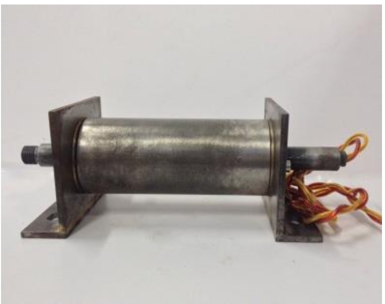


Fig. 2. Photograph of the damper.

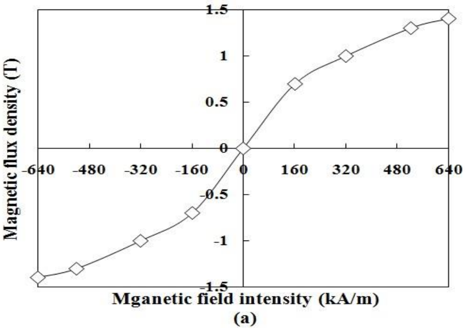
Table 1. Basic parameters of the metal foam MR fluid damper.

Working gap g	Thickness of metal foam s	Effective Length L_2	Coil groove width L_1	Thickness of working cylinder t	Diameter of piston D	Diameter of piston core d
1	2	20	50	10	38	16

3. Simulation methods

3.1. Simulation preparation

20# steel is chosen as materials of piston and working cylinder. As mentioned above, MRF used in the paper is MRF-J01T, and its magnetic characteristics are described in Fig. 3.



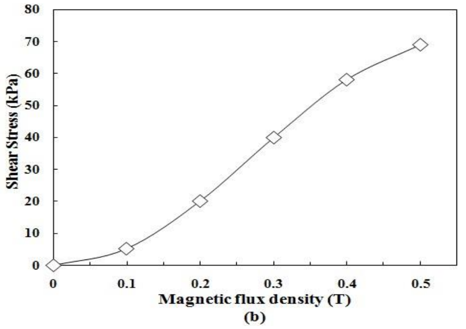


Fig. 3. Magnetic characteristics of MR Fluid-J01T.

3.2. Simulation process

Considering the symmetry of the damper, as shown in Fig. 4, 1/4 model is constructed to make magnetic field simulation. In the simulation, five kinds of material properties are needed defined, which contain piston, coil, working cylinder, metal foam and MRF. The relative permeability of piston, working cylinder, the coil and Ni is defined as 1200, 1200, 1 and 1.5 respectively. Material properties of MR Fluid-J01T are defined by B- H curve shown in Fig. 3 (a). The mesh result of the analysis model is presented in Fig. 5. After the magnetic flux parallel and source conductor are set, the magnetic field distribution and total magnetic induction intensity can be acquired through simulation. Taking 1.0A for example, the magnetic field distribution and the magnetic flux density in working gap of metal foam Ni MR fluid damper are shown in Fig. 6 and Fig. 7.

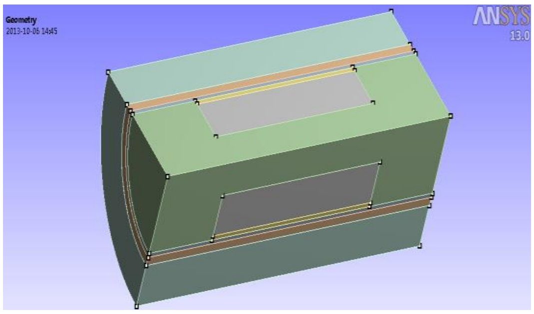


Fig. 4. Analysis model of the damper.

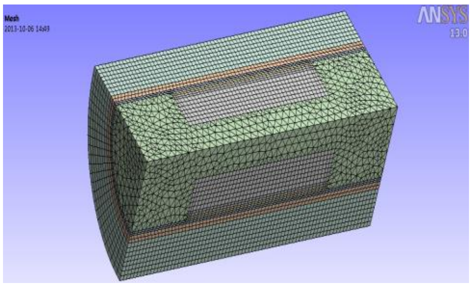


Fig. 5. Mesh result of the model.

3.2.1. The effect of different currents on magnetic induction intensity

This part aims to analyze the relationship between excitation currents and the magnetic induction intensity in working gap, through which the change tendency and the saturation point can be obtained easily.

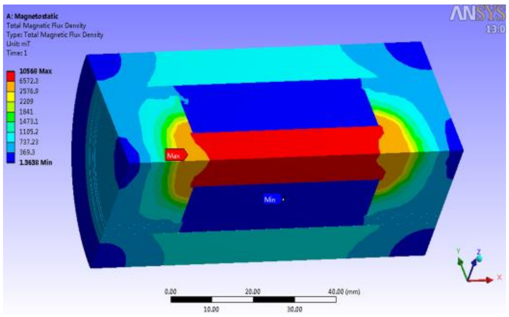


Fig. 6. Magnetic field distribution.

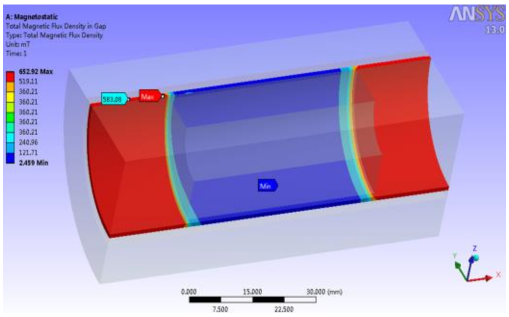


Fig. 7. Total magnetic induction intensity in the gap.

Numbers of magnetic field simulation on current of 0.04A, 0.08A, 0.1A, 0.5A, 1A, 1.5A, 1.8A and 2A for metal foam Ni MR fluid damper have been made. At the same time, in order to observe and make a comparison of the relation between the current and magnetic flux density under different working gaps intuitively, dampers whose shear gaps are 0.5mm, 1mm, 1.5mm and 2mm are compared.

4. Simulation results and discussion

The relation curves of magnetic induction intensity versus excitation current on the four gaps from 0.5mm to 2.0mm with the increment of 0.5mm are received in the part. The relationship between the magnetic induction intensity and current in different working gaps is compared and shown in Fig. 8 and 9. It comes to the conclusion that the changing tends of magnetic induction intensity with the change of current are basically consistent. And the tendency can be elaborated as that the magnetic induction intensity increases rapidly with the current raging from 0 to 1.0A, especially increases linearly between 0 and 0.5A, however, there is a slower increasing from 1.0A to 1.5A, and there are no more increments above 1.5A due to the magnetic saturation. In addition, as presented in Fig. 10, under different currents, the magnetic induction intensity decreases with the increase of the gap width for the reason that the total magnetic resistance of the magnetic circuit decreases with the decrease of the working gap, and the magnetic flux density is inversely proportional to the gap width.

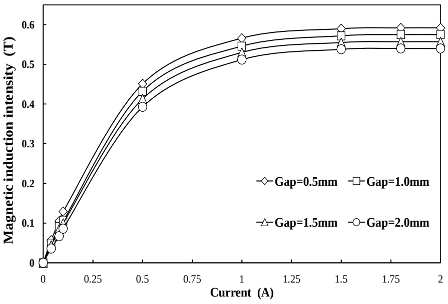


Fig. 8. Magnetic induction intensity vs. current.

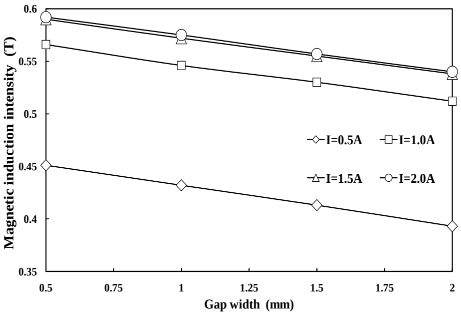


Fig. 9. Magnetic induction intensity vs. gap.

5. Conclusions

The purpose of the paper is to investigate the magnetic field distribution of the metal foam MR fluid damper through simulation and analysis the effects of some parameters on the damper.

The strength of magnetic field depends on excitation, so current is one of key factors for the performance of the damper. From simulation results, the conclusion shows that with the increasing of the current, the magnetic induction intensity increases, however, once the current is above 1.5A, the increment is not obvious longer due to magnetic saturation. Gap width also plays an important role in the performance of the damper, which can be found from the simulation results. The conclusion can be stated that the magnetic induction intensity is inversely proportional to the gap width ranging from 0.5mm to 2.0mm, which will lay a foundation for the optimal design of the metal foam MR fluid damper.

Acknowledgements

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