Shear Performance of a Metal Foam Magnetorheological Fluid Damper

Xuhui Liu, Xiaoli Gao, Fang Li, Hao Yu, and Dun Ye

School of Mechanical Engineering, Shanghai Institute of Technology, Shanghai 201418, China

This paper mainly investigates the shear performance of a metal foam magnetorheological (MR) fluid damper. As for the damper, MR fluids are stored in metal foam in the action of magnetic field, MR fluids are drawn out from the metal foam, and then fill the shear gap, thus producing the MR effect. Based on previous research, as a sample, the metal foam nickel (Ni) is applied to store MR fluids, and the metal foam Ni MR fluid damper is designed and manufactured. A test rig, including the metal foam MR fluid damper, dc motor with speed controller, force sensor with amplifier, and DAQ card and PC with LabVIEW software, is built to study the shear performance. The effects of excitation current and shear rate on damping force are analyzed. Besides, considering the influence of different currents on magnetic field, a series of magnetic field simulations on the damper are carried out in ANSYS FEM software. The results show that the excitation current is the key factor to damping force of the damper; with the increasing of the current, the damping force will increase. However, once the current is above 1.5 A, the increment is no longer obvious. Besides, damping force will decrease with the share rate increasing.

Index Terms—**Magnetorheological (MR) fluid damper, metal foam, shear performance.**

I. Introduction

MAGNETORHEOLOGICAL (MR) fluid is typically composed of two phases, such as magnetic particles (of size 3–10 μm) and hydrocarbon magnetic particles (of size 3–10 μm) and hydrocarbon. As a kind of smart material, MR fluid will behave as any other liquids in the absence of the magnetic field, in the presence of an external magnetic field, it can transfer from a free-flowing liquid state to a semisolid state of chain-like structures in a few milliseconds, besides, the transition is reversible [1]–[4]. Owing to the characteristics of MR fluid, it is possible and feasible to make significant application on the vehicle suspension, engineering structures, vibration control, and other fields [5]–[8].

Over the past few decades, MR fluid with unique advantages has drawn significant attention in research and applications [9]–[15]. However, the two key factors of traditional MR fluid dampers to limit much wider application are the relatively high cost and short lifetime. Carlson [16] specified the major factors leading to high cost, which can be described as special sealing devices to stop the leakage of MR fluid, precision mechanical tolerances, surface finishing of the moving piston rod, and the volume of MR fluid. In addition, for the lifetime of MR fluid dampers, with moving of the piston rod, the suspended particles in the MR fluid is easy to get into the sliding contact of the seal, which will cause quite serious damage to the surfaces. As mentioned previously, Chrzan and Carlson [17] proposed a MR fluid damper with the idea of using a porous sponge to contain MR fluid in which the sponge is wrapped around the piston and stores a relatively small amount of MR fluid, thus, no sealing devices in the damper are used. However, the sponge MR fluid damper also has the following shortcomings, such as, in order to ensure enough amounts of MR fluid, the relatively large thickness of sponge is required which will result in the low-magnetic field strength. In addition, it is also an important question that the porous sponge has a low intensity, which will make its lifetime short. Therefore, our previous researches [18] and [19] introduced a new MR fluid damper with the idea of using the metal foam, which is a stronger type of porous material to store MR fluid. On the application of external magnetic field, MR fluid stored in the metal foam will be extracted to fill into the gap, and the previous research has shown the metal foam MR fluid damper has obvious MR effect. The design using metal foam to store and release MR fluids will reduce the cost of conventional MR fluid damper, in addition, as the strength of metal foam is larger than the sponge, the lifetime of the metal foam MR fluid damper is also extended.

In recent decades, simulated analysis and performance investigation of MR fluid dampers also have attracted a significant attention of researchers. Parlak *et al.* [20] proposed the idea of using electromagnetic analysis of magnetic field and computational fluid dynamics (CFD) analysis to acquire optimal values of a MR fluid damper, in which, certain parameters, including excitation current, piston head housing thickness, gap width, and so on were analyzed. Liu *et al.* [21] studied the feasibility of using metal foams to store MR fluids experimentally, and the shear performance and response time were investigated; however, the study was based on the two-plate configuration. Yao *et al.* [19] primarily researched the response time of the metal foam MR fluid damper.

In this paper, the shear performance of the metal foam MR fluid damper is investigated experimentally, besides, the electromagnetic analysis of magnetic field in the damper is accomplished by ANSYS workbench. As the major parameter to evaluate the performance of the metal foam MR fluid damper, the influences of applied current and piston shear rate on the shear fore are studied experimentally. In addition, to

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