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Fuzzy-PID Controller for Semi-Active Vibration Control Using Magnetorheological Fluid Damper

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Abstract

Magnetorheological (MR) dampers are considered as excellent prospect to the vibration control in automotive engineering. To overcome the effect from road disturbances many control algorithms have been developed and opted to control the vibration of the car. In this study, the methodology adopted to get a control structure is based on the experimental results. Experiments have been conducted to establish the behaviour of the MR damper. In this paper, the behavior of MR damper is studied and used in implementing vibration control. The force-displacement and force-velocity response with varying current has been established for the MR damper. The force for the upward motion and downward motion of damper piston is found increasing with current and velocity. In the cycle mode which is the combination of upward and downward motion of the piston, the force having hysteresis behaviour is found increasing with current. Results of this study may serve to aid in the modelling of MR damper for control applications.

Keywords: Magnetorhelogical fluid, MR damper, semi-active vibration, Fuzzy-PID

Nomenclature

m	Mass
k	Spring constant
d	Damping constant
x	Distance
f	Force

1. Introduction

There are mainly three types of control devices: passive devices, active devices and semi-active devices. Semi-active devices offer the versatility and the adaptability of active device, and the reliability of the passive device. They can operate with power supply (active device) and without power supply (passive device). Magnetorheological (MR) dampers, variable orifice dampers and tuned liquid dampers are examples of semi-active devices.

MR fluids have been regarded as a smart material. Varying external magnetic field strength is used to vary and control the rheological properties of MR fluids. A typical MR fluid contains 20–40% by volume of relatively pure, soft iron particles having a dimension of 3 to 5 microns. These particles are suspended in mineral oil, synthetic oil, water, or glycol. A variety of proprietary additives similar to those found in commercial lubricants are commonly added to discourage

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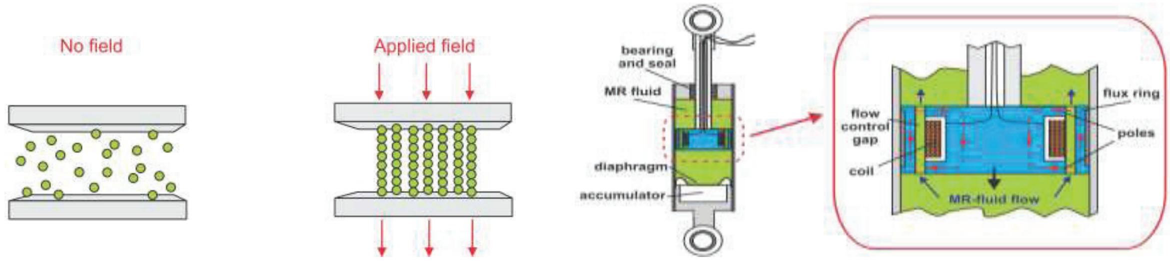
gravitational settling and promote particle suspension, enhance lubricity, modify viscosity, and inhibit wear [1]. In the absence of an applied field, MR fluids exhibit Newtonian-like behaviour. However, in the presence of an applied magnetic field, the iron particles acquire a dipole moment aligned with the external field which causes the particles to form linear chains parallel to the field, as shown in Figure 1(a). This phenomenon can solidify the suspended iron particles and restrict the fluid movement.MR fluid damper or MR damper consists of MR fluid inside and it uses the properties of MR fluid in controlling the vibration of a system. The magnitude of force that an MR damper can deliver depends on the properties of MR fluids, their flow pattern, and the size of the damper. Figure 1(b) represents the structure of MR damper.

Recently, MR fluid dampers have been widely applied to control and suppress unwanted vibration and shock for various systems including-landing gear, helicopter lag dampers, vibration isolation systems, vehicle seat suspension systems, civil structures, military equipments, prosthetic limbs. MR dampers possess key performance advantages, including continuously controllable force, rapid response, and low power consumption, which can be readily optimized in design procedures [2-3]. MR dampers can be analyzed using available models and are amenable to innovative design concepts [4-5].



(a) (b)

Figure 1: (a) Chain-like structure formation in MR fluids [6-7], (b) Typical MR damper [6-7]

To practically construct vibration and shock mitigation systems using MR dampers, either a power supply or a current amplifier is required to activate the electromagnetic coils in the MR dampers to supply magnetic field to the MR fluid.

There are some key parameters which influence the MR damper's performance. However, there is no simple and effective parametric model with high accuracy for MR damper, though various kinds of models have been proposed and validated [8]. In recent years, researchers are studying ways to improve the performance of MR fluid damper. They are trying to fit the existing well-established models into their investigations with new ideas to achieve better performance. The main problem is the complexity encountered in implementing these models due to the large number of parameters that need to be estimated. The most popular ideas are based on the parametric solutions. These ideas, however, cannot describe the real phenomena of nonlinear system.

In this study a simple technique based on the experimental result is suggested to control the vibration with MR damper. As this study is about experimental identifications, it solves the issue of evaluating too many parameters. This paper has tried to establish the characteristic analysis of MR damper with impedance (Force/Velocity) analysis. The main contribution is to achieve a new performance based model of magnetorheological damper. The experimental investigation and the performance analysis are the key for this methodology. This performance test is based on the dynamic force-displacement-current (surface) analysis.

2. Experimental Setup to establish behavior of MR damper

The experimental setup comprises the MR damper, the wonder box, and a Universal Testing Machine (UTM) which are shown in Figure 2. The UTM was used to test the MR damper. The UTM has an upper and a lower head with grippers that can grasp the damper at the appropriate locations. The upper head is operated by a hydraulic actuator which can take a computer-generated prescribed displacement signal and is the moveable end. The lower head incorporates a load cell, allowing the operator to measure the force applied to the MR damper. The displacement of the damper is measured by a Linear variable differential transformer (LVDT) sensor which is integrated with the test machine. During the experiment, a variable voltage was supplied to provide the current excitation to the damper-coil. The required signal was generated using TRAPEZIUMX software running on a computer and the data was obtained from the software.

The MR damper used in this experiment is a product of LORD Corporation, USA. The model number of the particular MR damper is RD-8041-1. The stroke length of the damper is 74 mm and the maximum tensile strength is 8896 N. MR fluid device controller kit, namely Wonder Box Device Controller (Model: LORD RD-3002-03 Wonder Box Device Controller), is a companion product of the MR fluid devices. It provides closed loop current control to compensate for