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Experimental Analysis of Fabricated Magnetorheological Damper by Using Different Magnetorheological Fluid: A Review

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Abstract

Magnetorheological (MR) fluid damper are semi active control device have been applied a wide range of practical vibration control application. The application of magnetorheological (MR) dampers to give damping by the shear stress of MR fluids for reduces the shock vibration of mechanical system. A MRF damper has the property that's damping changes quickly in response to an external magnetic field strength. In this paper investigated theoretically at fabricated magnetorheological damper by using different magnetorheological fluid. Here a new type of MR fluid developed by mixing of prepared nano size iron particle by co precipitation method. And experimental performs on fabricated MR damper, by changing size and percentage of iron particle discussed.

Keywords: Magnetorheological (MR) fluids; Magnetorheological dampers; Semi-active damper; nano particle; Magnetic field intensity.

Introduction

The suppression of mechanical and structural vibration using semi-active control method has been actively worked by many researchers in last two decades. Recently, various semi-active suspension systems featuring MR fluid damper have been proposed and successfully applied in the real field, especially in vehicle suspension systems. MR fluid dampers applied to control 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. The main advantages are that they need very less control power, has simple construction, quick response to control vibration. A MR Damper or MR shock absorber is filled with MR fluid, a smart material, which is controlled by a magnetic field, usually using an electromagnet. This allows the damping characteristics of the shock absorber to be continuously controlled by varying the power of the electromagnet. The magnetorheological damper Models are accurately represent the behavior of MR fluid for better understanding the operation and working principles of the device. The initial discovery and development of MR fluids can be credited to Jacob Rabinow at the US National Bureau of Standards in the late 1940s.

The magneto-rheological fluid is a type of smart fluids whose rheological properties (elasticity, plasticity or viscosity) change in the presence of magnetic field. It consist of ferromagnetic particle size (micron or nano meter range) mixed with carrier fluid typically a synthetic or hydrocarbon based oil.

MR fluids made from iron particles exhibit maximum yield strengths of 50-100 kPa for applied magnetic fields of 150-250 kA/m. MR fluids are not highly sensitive to moisture or other contaminants that might be encountered during manufacture and usage. Further, because the magnetic polarization mechanism is unaffected by temperature, the performance of MR-based devices is relatively insensitive to temperature over a broad temperature range (including the range for automotive use). MR fluids are usually applied in one of two modes. MR fluid operating in valve mode, with fixed magnetic poles, may be appropriate for hydraulic controls, servo valves, dampers, and shock absorbers. The direct-shear mode with a moving pole, in turn, would be suitable for clutches and brakes, chucking/locking devices, dampers, breakaway devices and structural composites.

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MR Dampers have over the last several years, been recognized as having a number of attractive characteristics for use in vibration control application. MR dampers are promising devices for vibration mitigation in structure; due to their low cost, energy efficiency and fast response. To use these dampers efficiently it is necessary to have models that describe their behavior with a sufficient precision.

Working Principle

The MR Damper is one such semi–active control system that is being recommended to dissipate structural vibrations**.** MR fluid damper is a device to give damping by the shear stress of MR fluid. A MR damper has the property whose damping changes quickly (within μs) in response to an external magnetic field strength. The magnetic flux path is formed when the electric current puts through the solenoidal coil. As a result, the particles are gathered to form the chain-like structures, with the direction of the magnetic flux path. These chain-like structures restrict the motion of the MR fluid, thereby increasing the shear stress of the fluid. The damper can be achieved by utilizing the shear force of MR fluid. The damping values can be adjusted continuously by changing the external magnetic field strength.

Literature Review

The following literature review describes important research results regarding the experimental analysis of fabricated magnetorheological damper by using different magnetorheological fluid.

Nitin Ambhore,Shyamsundar Hivarale,Dr. D. R. Pangavhane (2013) They presented a Bouc-Wen Model and Modified Bouc-Wen model for a magnetorheological damper. and study the hysteretic relationship between the damping force and the velocity. to evaluate the performance of MR dampers in vibration control applications and comparing the modified phonological Bouc-Wen model with the simple Bouc-Wen model, and find out that an internal displacement. They introduced the model to better behavior of the magnetorheological damper**. [1]**

Meng-Gang Yang, Chun-Yang Li, Zheng-Qing Chen(2013) They presented a new simple non-linear hysteretic model for MR damper and represent the hysteretic behavior of them. They are use RD1097 type MR damper manufactured by Lord Corporation. Then the Model's parameters are identified by the non-linear least square method from test data and fitted by the polynomials as functions of the supplied current. Finally, the accuracy and the effectiveness of the model are demonstrated by the RMS errors comparison between the reconstructed hysteretic curves and the experimental**. [2]**

Francesc Pozoa, MauricioZapateiro, LeonardoAcho, Yolanda Vidala(2013) They studied at the problem of vibration in suspension systems and equipped with a magnetorheological damper which is a semi active nonlinear device. Three different controllers were proposed and experimentally tested. And the implementation of the controller implied a better performance than the use of a purely passive device. Despite the performance of all the controllers is comparable, the one based on the updating term yielded the best results among them all The controllers proposed have proved to be robust and their simplicity and ease of implementation encourage further studies for its practical use in large scale systems including vehicles and civil structures where this kind of dampers finds important applications. **[3]**

M.T. Braz-Cesar, R.C. Barros (2012) They presented the experimental testing and numerical modeling of the RD-1005-3 MR damper manufactured by Lord Corporation. To predict the behavior of the MR damper. They find out the usual approach to determine the MR damper behavior involves measuring the MR damper response at a constant operating current level (or voltage) under a sinusoidal displacement of the damper piston. The experimental data will be presented and analyzed to used and identify the model parameters that are required to develop some parametric models for this device. These models must predict the experimental nonlinear hysteretic response of the MR damper in the whole operating range to allow developing an accurate numerical model. **[4]**

Fengchen Tu, Quan Yang, Caichun He, Lida Wang(2012) They are designed a single piston rod MR damper with an accumulator in order to satisfy with the demand of a certain automobile front suspension. The damper structural parameters were obtained by integrated optimal design combining magnetic circuit and structure. Magnetic circuit was analyzed by means of finite element method. The calculating formula derivation of damping force of MR damper with an accumulator was also achieved. Then the properties of designed damper were investigated by experiments, and the relationship between damping force, circuit and speed was fitted by the experimental results. This work provided promising method for the experimental study and design on automobile suspension made of MR damper. **[5]**

S-evki, C- es-meci, TahsinEngin(2010) In this study, an experimental and a theoretical study were carried out to predict the dynamic performance of a linear magnetorheological (MR) fluid damper. After having designed and fabricated the MR damper, its dynamic testing was performed on a mechanical shock machine. A theoretical flow analysis was done based on the Bingham plastic constitutive model to predict the behavior of the prototyped MR damper. The theoretical results were then validated by comparing them against experimental data, and it was shown that the flow model can accurately capture the dynamic force range of the MR damper. In addition to the flow model, a modified parametric algebraic model was proposed to capture the hysteretic behavior of the MR damper. **[6]**

Zekeriya Parlak, TahsinEngin (2012) The Magnetorheological (MR) dampers can be controlled effectively by a magnetic field and with minimum power requirement. Under the magnetic field, MR fluid behaves as a non-Newtonian fluid with controllable viscosity. Damper performance can be enhanced by getting to know better the non-Newtonian flow in the annular gap of piston head**.** In the study the non-Newtonian flow in the annular gap is investigated by a quasi-static analysis that enables to calculate plug thickness and damper force. Also CFD analysis of the MR damper is performed by using transient and deformed mesh to be able to simulate moving of piston head in the damper considering non-Newtonian regions. Results of the analyses have been compared to experimental data obtained from MR dampers. **[7]**

Mukund A. Patil, Swapnil Sapkale, Sagar Soni.et al.(2012) They investigated the geometric design method of a cylindrical MR fluid damper theoretically. And developed damping by MR fluid within the damper under different magnetic field strength conditions. is analyzed and tested at the Indian Institute of Technology, Bombay. They are also derived engineering design calculations related to volume, thickness and width of the annular MR fluid within the damper. And calculated parameters of the thickness and width of the fluid in the damper from the equations obtained, when the required mechanical power level, the speed of the piston, and the desired control damping ratio are specified. The design method of a new MR fluid damper is investigated theoretically and the structure is presented in this paper. **[8]**

Hamid Reza Karimi (2011) they studied the application of semi-active suspension for the vibration reduction in a class of automotive systems by using MR dampers. Back stepping and heuristic controllers have been proposed: the first one is able to account for the MR damper's nonlinearities and the second one needs only the information of the measured vibration. The control performance has been evaluated through the simulations on an experimental vehicle semi-active suspension platform. **[9]**

K.H. Lam, Z.H. Chen, Y.Q. Ni, H.L.W. Chan (2010) in this paper a magnetorheological (MR) damper with embedded force and displacement sensors is devised to facilitate closed-loop structural vibration control. A piezoelectric force sensor and a linear variable differential transformer (LVDT) have been integrated with a conventional MR damping device. The piezoelectric sensor is used to sense the damping force produced by the damper, while the LVDT is employed to measure the displacement of the vibrating structure at the damper location and the movement of the damper piston. The sensing and damping performances of the devised MR damper are evaluated under displacement-controlled excitations, with different current inputs being commanded to the damper. The experimental results demonstrate reliable displacement/force sensing and controllable damping capabilities of the devised damper. **[10].**

A.G. Olabi, A. Grunwald (2007) they are presented a technical report on Design and application of magneto-rheological fluid. In this report an actuator with a control arrangement based on MRF technology are studied and shows that excellent features like fast response, simple interface between electrical power input and the mechanical power output, and controllability make MRF the next technology of choice for many applications. they also describe the mode of MR fluid (like valve, shear, Squeeze) and compared on ferro & magnetorheological fluid.**[11].**

Andrzej Milecki (2001). In this paper A semi-active controllable fluid damper is described and studied a simulation model of those dampers is proposed and some control analyses are made. Construction of such a damper is described and finally experimental results of its performance are presented. The uses of an active MR fluid damper proposed and solve the oscillation problem without decreasing the gain coefficient. The main disadvantage of these solutions is the cost and complication of the servo drive and the control systems. [**12].**

Jeong-Hoi Koo, Fernando D Goncalves and Mehdi Ahmadian(2006) This study introduced a method for the experimental determination of the response time of MR dampers. Several parameters and their effect on the response time of MR dampers were evaluated. The response time of an MR damper was found for various operating currents and piston velocities. The authors intend to develop a method for the definition and the experimental determination of the response time of MR dampers. Furthermore, parameters affecting the response time of MR dampers are investigated. Specifically, the effect of operating current, piston velocity, and system compliance are addressed **[13].**

W H Liao and C Y Lai (2002) They studied a single-degree-of-freedom (SDOF) isolation system with an MR fluid damper under harmonic excitations. A mathematical model of the MR fluid damper with experimental verification of MR damper are studied and compared with a conventional viscous damper. The energy dissipated and equivalent damping coefficient of the MR damper in terms of input voltage, displacement amplitude and frequency are investigated. The relative displacement with respect to the base excitation is also quantified and compared with that of the conventional viscous damper The results of this study are valuable for understanding the characteristics of the MR damper to provide effective damping for the purpose of vibration isolation or suppression. **[14]**

Zekeriya Parlak, Tahsin Engin, Ismail Call (2012) The purpose of the study was to optimize MR damper geometrically in accordance with two objectives, target damper force as 1000N and maximum magnetic flux density. The optimization studies were carried out by finite element method using electromagnetic and CFD tools of ANSYS v12.1. The FEM analyses were employed to get desired optimal values in ANSYS Goal Driven Optimization tool. Values of optimal of the design parameters of the MR damper were searched between lower and upper boundaries in both electromagnetic and CFD analyses. The parameters were geometrical magnitudes, current excitation and yield stress. **[15]**

A. Ghiotti, P. Regazzo, S. Bruschi, P.F. Bariani (2010) They investigated the application of magneto-rheological (MR) dampers to reduce the shock response of press systems is considered with the aim of evaluating, through full-scale experiments, feasibility and practicability of their implementation and understanding the potential benefits in comparison with conventional dampers. They developed for metalworking presses to withstand the break through shock generated during blanking operations**.[16]**

A. Ashfak, K.K Abdul Rasheed, J. Abdul Jaleel (2013) They was to study the application of an MR damper to vibration control, design the vibration damper using MR fluids, test and evaluate its performance. This MR damper was tested and the results were obtained in the form of force vs. velocity. This damper is modeled in Ansys and analysis was carried out. And force vs. velocity graph is plotted. The graph obtained by simulation is validated with the experimental result**. [17]**

A. Rodr´ıguez, F. Ikhouane, J. Rodellar, N. Luo(2008) They are briefly described the way of identify of magnetorheological damper, in this paper two of these models are explored: a normalized version of the Bouc-Wen model and the Dahl friction model. A methodology for identification is proposed, and the obtained models are tested theoretical and validated experimentally. To use these dampers efficiently it is necessary to have models that describe their behavior with a sufficient precision**.[18]**

Weng W. Chooi, S. Olutunde Oyadiji(2008) They presented a procedure for obtaining exact solutions to describe the flow of MR fluid through an annular gap. The working equations are general expressions that can be applied on any model of fluid with a yield stress. The velocity profile of this flow has an asymmetric characteristic and the plug region decreases as the flow increases. The solution was validated by computational fluid dynamics analysis. a mathematical model of the double-tube MR damper was developed using the annular flow solutions and incorporating fluid compressibility. Physical parameters for the model were identified via an optimisation routine implemented in Matlabtm/SimulinkTM.**[19]**

Mehdi Ahmadian , James A. Norris(2008) This study provides an experimental analysis of magnetorheological dampers when they are subjected to impact and shock loading. drop-tower is developed to apply impulse loads to the dampers. the drop-tower design uses a guided drop-mass, which is released from variable heights to achieve different impact energies. They are use two MR damper configurations and tested, a damper with a single-stage, double-ended piston and a mono-tube damper with a two-stage piston. they was developed a method for study the behavior of MR fluids subject to impulse loads. Two fundamental MR damper designs were subjected to five impact velocities. At each impact velocity, five supply currents were tested. Each test was repeated three times**. [20]**

Q H Nguyen, S B Choi and K S Kim (2009) they studied, geometric optimal design of vehicle MR dampers, based on FEM solution was performed using ANSYS parametric design language. The optimization problem was to identify geometric dimensions of the valve structure employed in the MR damper that minimizes an objective function. the objective function was proposed considering the damping force, dynamic range and the inductive time constant of the damper and their reference values. The reference values were determined based on the assumption of constant magnetic flux density throughout the magnetic circuit of the damper**. [21]**

S. Kciuk , R. Turczyn , M. Kciuk(2010)they are studies of a prototype magnetorheological damper at various magnitudes of control current as well as the manner of modelling electromagnetic phenomena occurring in the damper. they was prepared model MR fluid using silicone oil OKS 1050 mixed with carbonyl iron powder CI. Furthermore, to reduce sedimentation, as stabilizers was added Aerosil 200. That elaborated model can be use for modeling the semi active car suspension dynamics. for determining the dynamics properties of this type of mechanical systems, they employing the finite element method and using ANSYS software.**[22]**

Md. Sadak Ali Khan, A.Suresh, N.Seetha Ramaiah (2013) they presented a study is to evaluate and understand the performance of the Magnetic – Rheological (MR) damper. its performance depends upon the magnetic and hydraulic circuit design. This work deals with design of an MR damper for which mathematical model is developed. A finite element model is built to analyze and investigate the performance of 2-D axi-symmetric MR damper. Various configurations of damper piston with different number of turns and pole lengths are simulated.. The input current to the coil and the piston velocity are varied to evaluate with the change in magnetic Field Intensity (H) and damping Force. They evaluate the different models of MR damper using ANSYS software. **[23]**

G.Z. Yao , F.F. Yap, G. Chen, W.H. Li, S.H. Yeo (2002) they presented a semi-active control of vehicle suspension system with magnetorheological (MR) damper. A flow mode of MR damper designed and Performance testing is done for this damper with INSTRON machine. Then a mathematical Bouc–Wen model is adopted to characterize the performance of the MR damper. And optimize in MATLAB. A scaled quarter car model is set up including the model of the MR damper and a semi-active control strategy is adopted to control the vibration of suspension system.**[24]**

Tamizharasi.g, ajit kamath, kaustav sen gupta and umesh. G (2012) they discussed a semi-active control device which can operate under very low power requirement. Magnetorheological (MR) damper is one of the new technologies designed using MR fluids to produce controllable dampers to serve this purpose. Specially, MR fluid technologies are reliable, inexpensive, and relatively insensitive to temperature fluctuations. This type of damper has high dynamic range, low power requirements, large force capacity and robustness. And briefly discussed the behavior of MR fluid and its application in making MR damper**.[25]**

E. Świtoński, A. Mężyk, S. Duda, S. Kciuk(2007) they presented a concept of a system for isolation from external vibration sources with use of a magnetorheological (MR) dampers. A experimental studies of a prototype magnetorheological damper at various magnitudes of control current and the manner of modelling electromagnetic phenomena. The effect of magnetic field on magnetorheological fluid is modelled by the finite element method. The mathematical model of the system as well as the damper model are outlined along with the relevant control facilitiesThe elaborated damper and applied control algorithms substantially influences the values for velocities and accelerations.**[26]**

K. Hudha, H. Jamaluddin, P.M. Samin and R.A. Rahman (2005) they studied at Effects of control techniques and damper constraint on the performance of a semi-active magnetorheological damper. A number of semi-active control algorithms namely modified skyhook, modified groundhook and modified hybrid skyhook-groundhook controllers are evaluated to be used with a magnetorheological damper. The effectiveness of these control algorithms in disturbance rejection are investigated along with their ability to consistently provide the target force in the same direction with the damper velocity to overcome the damper constraint. the controllability of the MR damper model was verified by realising the closed-loop control system to track the desirable damping force.**[27]**

A. Ashfak, A. Saheed, K. K. Abdul Rasheed, and J. Abdul Jaleel (2011) they presented the design, fabrication and evaluation of magneto-rheological damper. Designed a new type of MR damper and studied on the behavior of MR fluid. The study of rheology as such, the theory behind rheological fluids, their properties and their application to vibration control. The design and fabrication of MR damper suited to vehicle suspensions were carried out. They also discussed the type of suspension system and type of MR damper with Mathematical calculation on MR damper**. [28]**

M. Zapateiro, N. Luo, J. Rodellar, A. Rodríguez (2008) They presented a case study is in which a base-isolated building containing an nonlinear control methodology MR damper is to be stabilized during a seismic motion. the simulations showed that the controller performs satisfactorily at reducing the structural response of a base-isolated building subject to a seismic motion. a back stepping controller is designed. The controller performance is evaluated by means of numerical simulations. Some observations about backstepping control experimentation are also made**.[29**

Butz, T.; von Stryk, O. (2002) they give an overview on the basic properties of electro- and magnetorheological fluids and discuss various phenomenological models for whole devices and their applications. Numerical simulation results are presented for the passive suspension of a quarter vehicle model. They used in suitable devices, they offer the innovative potential of very fast, adaptively controllable interfaces between mechanical devices and electronic control units**.[30]**

Conclusions

1. A Bouc-Wen Model and Modified Bouc-Wen model for a magnetorheological damper are accurately predicts the behaviour of the damper.

2. They conclude a new simple non-linear hysteretic model for MR damper has higher accuracy than the Bingham model.

3. They was found that the implementation of the controller implied a better performance than the use of a purely passive device

4. The Value of yield stress in Bingham plastic model varies with the applied current was obtained by magnetic flux density.

5. They conclude by minimizing the objective function, the yield stress force, dynamics range and conductive time constant are significantly improved at any value of applied current. The power consumption of the optimized damper was also significantly reduced.

6. They were concluded that the Bingham plastic model could not be capable of capturing the inherent hysteretic behavior of the MR damper.

7. They was observed that plug thickness and velocity increased by increasing of current. Rate of the rising decreased together with increasing of current especially bigger than 1A due to saturation.

8. They was concluded that the present mAlg model flow model can be successfully adopted to design and predict the dynamic behavior of MR dampers, while the mAlg model can be used to develop more effective control algorithms for such devices..

9. It has been shown that the proposed semi-active control strategies are capable of reducing the suspension deflection with a significantly enhanced control performance than the passive suspension system..

10. The MR damper with embedded force and displacement sensors has advantages in fulfilling real-time closed-loop feedback control applications for mitigating structural vibrations in a reliable and simple manner.

11 The design of the MR fluid dampers plays a significant role in their dynamic behavior during impact events.

12. The optimal design parameters of a MR damper getting damper force desired and maximum magnetic field that provides maximum controllability of the MR damper.

13. The response time play a more important significant on design of magnetorheological damper.

14. The semi-active controlled MR damper can achieve effective vibration suppression without the sacrifice of worse isolation for higher frequencies of interest.

15. The potential Benefit of MR dampers are more feasible and practicable in comparison with conventional dampers.

16. MR dampers proved to be effective in damping the vibrations induced by the break through shock

17. The damping force is very low for zero current and it increases gradually as the current is Increased. It means they are directly proportional to each other.

18. They can observe a tendency of the active system's higher vibration isolation efficiency in relation to the passive system along with the growing excitation frequency. Furthermore, active damping helps the vibrating object to reach its fixed state more quickly.

19. They observed that increase or decrease in the number of turns of coils and total pole length did not improve the performance of the damper in terms of damping force.

20. The damping coefficient increases with the electric current, but decreases with excitation amplitude.

21. They conclude The modified hybrid skyhook groundhook controller is also superior in overcoming the damper constraint by consistently providing the target forces with the same sign as the damper velocity.

22. They conclude semi-active control have very good control over the damping force, Also the controllable force is not zero at zero current which means the yield stress is never zero.

23. The damping force is very low for zero current and it increases gradually as the current is increased.

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