MAGNETO-RHEOLOGICAL DAMPERS IN AUTOMOTIVE SUSPENSIONS

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Abstract - *In recent years, a flutter of enthrall has been shown for a technology called Magneto Rheological Fluids. Multiple types of equipments have been designed to implement MR fluid like linear dampers, clutches, brakes and shock absorbers. The devices have been used in automobiles, washing machines, medical equipments and even smart structures. This paper focuses on one of its application of MR fluid in automobile suspension. An experimental examination is carried out to show the efficiency of using MR Fluids on conventional shock absorber of the automobiles. The MR dampers provides a more stable ride than that of the OEM shock absorbers. By downgrading the settling time, suspension displacement, and suspension oscillations, the MR dampers were able to reduce instability of suspension geometry. It is found that the efficiency of damper used in this study increases by using MR Fluids, Since we can vary the viscosity of fluid with the applied current on the MR damper .*

Key Words: Applied Current, Bingham Plastic, MR Dampers, Viscosity .

I. INTRODUCTION

suspension is the system that connects a frame of vehicle to its wheels and allows relative motion between them.It consists of shock absorber, spring and linkages. Suspension systems bestow a purpose of contributing to the vehicle's road handling/holding and braking for fertile operational safety and driving delight, and keeping vehicle occupants comfy and consequently well isolated from road undulations, bumps, and vibrations. It is important for the suspension system to keep the tyre in contact with the road as much as possible for better traction.

Damping is the curbing of motion or oscillation with the use of valves and hydraulic gates in a vehicle's shock absorber. Damping may also vary, deliberately or non-deliberately

Damping controls the travel speed of the vehicle's suspension. A car without damper will oscillate up and down. With proper damping, the car will come back to its normal state in a minimal amount of time. Most of the damping in modern vehicles can be controlled by increasing or decreasing the viscosity to fluid flow in the shock absorber which leads to the concept of Magneto-Rheological Fluids.

A. Types of suspensions

1. Passive suspension

Conventional springs and dampers like coil spring, leaf spring, etc are referred to as passive suspensions — most vehicles are suspended in this manner.

2. Active suspension

suspension are the suspension in which with the help of onboard system damping can be control which in passive suspension purely depends on road irregularities. Active suspension are further divide into fully active and semi active suspensions. In fully active suspension actuators are used that case lift chassis as per the road irregularities while in semi-active suspension viscosity of fluid can be vary which can give required damping.MR Dampers stands in semi-active suspension family.

II. MAGNETO RHEOLOGICAL FLUIDS

A. Introduction

A typical Magneto-Rheological fluid consists of 20-40 percent by volume of pure, 3-10 micron diameter iron particles that are suspended in a carrier liquid such as synthetic oil, water or glycol. A multiple of proprietary additives are added in commercial lubricants to hinder gravitational setting and promote particle suspension. For most engineering applications, the Bingham plastic model is effective in describing the field-dependent fluid characteristics.

Magneto-Rheological fluid are contains iron particles which exhibit the maximum yield strengths of 50-100 kPa for the applied magnetic fields of 150-250 kA/m. Magneto-Rheological fluid is not sensitive to moisture or other contaminants that might be encountered during its usage. Since viscosity of fluid can be changed accordingly it makes Magneto-Rheological fluid insensitive to temperature , to which passive suspension are sensitive.

B. Features and Benefits

- Fast Response Time
- Dynamic Yield Strength
- Temperature Resistant
- Hard Settling Resistant
- Non-Abrasive

C. Working

In normal state the iron particles are randomly distributed throughout the solution. After magnetic field has applied iron particle shall adjust themselves in uniform layer.

Types of Mode

Valve mode

The fluid is located between the stationary poles. The resistance to the fluid flow is curbed by varying the magnetic field between the poles, in a direction perpendicular to the fluid flow. Servo-valves, dampers, shock absorbers and actuators are the devices that are using valve mode of operation.

Direct shear mode

In this mode the fluid is located between a pair of moving poles. The relative displacement is parallel to the poles. The damping force applied by the fluid to the moving surfaces can be controlled by varying the magnetic field between the poles. Clutches, brakes, locking devices and dampers are the devices using direct shear mode of operation.

Squeeze mode

In squeeze mode the fluid is located between a pair of moving poles. The relative displacement is perpendicular to the fluid flow's direction. The compression force applied to the fluid is varying. Displacements are small compared to the other modes but damping forces are high. The squeeze mode has been explored for its use in small amplitude vibration and impact dampers.

III. MAGNETO RHEOLOGICAL DAMPERS

A. Construction of MR Damper

(a) (b) (c)

(d) (e) (f)

Fig 1 Shows the various parts of the Suspension: (a) Twin tube suspension, (b) Damper, (c) Outer cylinder, (d) Inner cylinder, (e) Piston and piston rod, (f) Valves with orifice

Above figure shows the various parts of the suspension, which will provide for the damping function of the whole unit, as our model required a magnetic field around the working fluid, necessary modifications had to be made to the original construction of the suspension, which are in below figure.

(a) (b) (c)

Fig.2 Shows the suspension after the modifications done on the original suspension (a) Solenoid wound over the inner cylinder, (b) Welded lower section of the inner cylinder, (c) Assembly of suspension with modifications.

The modifications include, getting rid of the seal valve at the bottom of the inner cylinder and welding a piece of mild steel with similar cross---section at the same point, which will provide for stopping fluid transfer from inner cylinder to outer cylinder, and retain the working fluid within the cylinder. This converts the twin tube into a mono tube construction. The other addition is wounding a solenoid over the inner cylinder, over a length of 80mm from a point 10mm below the opening of the inner cylinder (working area of the fluid) . The coil will induce a magnetic field around the working area after provision of an e.m.f.

B. Working

Once the suspension is locked into position using the mounting points, the coil input and output points will connected to a constant current source. Once the system is switched on, a constant current runs through the coil, this will generate magnetic field lines around the core (being the inner cylinder). Now this magnetic field lines will cause the iron particles within the fluid to align themselves with the field lines, intensifying the concentration of particles along those lines. This will cause the fluid to turn from a liquid to a semi--solid state and viscosity eventually increases.

The increased viscosity results in increased resistance force at the piston during its motion, and hence leading to increased damping effect. The mode of operation would be squeeze valve mode. Valve mode is used around orifice in piston while squeeze mode will take place between top of piston and cylinder head.

C. Setup

Fig.3 Tensile Test Machine & Constant Current Source Machine

The MR damper will be mounted onto two flat plates using two fixtures to provide a flat area for force application by the load cell of the test machine. This test machine is further connected to a computer (not shown in figure), which has the required software to carry out the analysis. The software will enable us to control vertical movement of load cell and the velocity at which it will move.

For the electrical connection, the terminals of the constant current source machine are connected to the coil wires, which are removed through holes in the outer tube, using crocodile clips.

D. Procedure

The suspension will be mounted between the sheet steel panels, one at the bottom to provide a flat base, and the second panel attached to the load cell on the cross member with vertical movement. The flat plates will hold the instrument, to be tested, in a fixed position and also distribute the load uniformly.

As the top and bottom ends of the suspension mountings have a curved surface, we had to incorporate fixtures shown in fig.4 that would hold the suspension firmly and also serve the purpose of transferring the load from the flat plates to the suspension

Below is the specification sheet for the Tensile Test Machine that we will be using for our experiment.

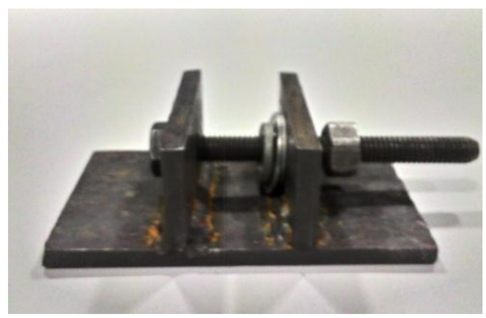

Fig.4 Fixture mounting used for suspension damper.

The above fixture is made from a mild steel plate of thickness 6mm, for both the upper and lower mounting points of the suspension and the process followed is as such:

1. Cutting of the long plate into required length, that includes dimensions of the base and the support.
2. Drilling holes through the supports, and should coincide with the holes at the suspension ends.
3. Welding the supports on to the base, separated by a distance equal to the width of suspension ends.
4. Finally procuring the necessary size of nut and bolt, with washers, to have a firm hold over the suspension.

Fig.5 Suspension placed on test bench with mountings

IV. FEMM SIMULATION

The Finite Element Magnetic Method (FEMM) software package is suitable for coil design, number of turns of the coils wrapping around the core, the current values through the coil, and material type of each component involved in the system. These parameters are the key to producing the best value for the magnetic field intensity H, which is associated with the magnetic flux density B, the concept mode of squeeze mode, design parameters and conditions are envisaged by FEMM.

The materials employed in this system can be divided into three classes; coils, non---magnetic and magnetic materials. The inner cylinder is made of magnetic material (mild---steel). Copper wire of Gauge 22SWG was taken for the coil to be wound around the cylinder. The non---magnetic components will be the piston rod and piston, which are of stainless steel. The MR damper was drawn based on asymmetric model in FEMM simulation as shown in Fig.6.

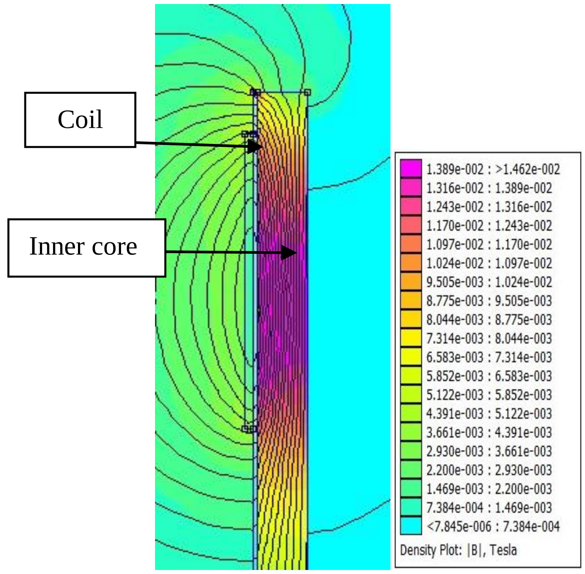

Fig.6 Asymmetric mode of MR damper in FEMM

The main purpose of using this software was to establish whether the magnetic field generated would penetrate the inner cylinder and what field intensity we could achieve at the core of the cylinder. And as Magneto-Rheological fluid is a composition of iron particles and carrier fluid, we decided to take the core as an iron core.

With the help of the density plot and by visualizing the color variance, we are able to determine the field intensity present within the system.

The graphs below portray the simulated results of variation of magnetic flux with the length of the inner cylinder, and with different values of current

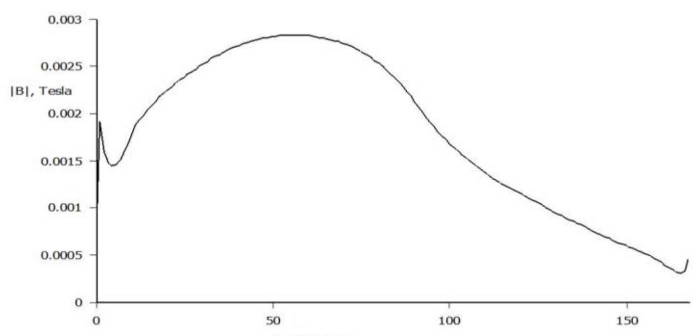

Fig.7 Variation of magnetic flux with length at 0.2A current

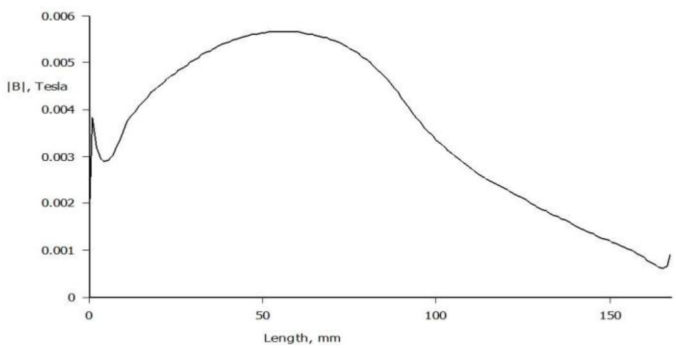

Fig.8 Variation of Magnetic flux with length at 0.4A current

Observing the graphs above, we can come to a conclusion that, as we increase current from 0.2A to 0.4A through the coil, the peak magnetic flux intensity increases from 0.00275B to 0.00575A. Alongside that we also notice that magnetic flux rises to a peak value which comes about at the midpoint of the coil i.e. 50mm from the top of the inner cylinder, and then descends to a steady value.

V. TESTING ON TINIOUS OLSEN TESTING MACHINE

A. *Requirements*

To carry out the test there were some parameters that were fixed and others related to it were varied. They are as follows:

1. Fixed parameters
   i) Piston travel length of 50mm
   ii) Velocity of piston movement---10mm/min

2. Variable parameter
   i) Current (0A, 0.2A, 0.4A)

Keeping a fixed velocity of 10mm/min for the movement of the load cell downwards, the reaction force due to the damping effect of the fluid, is sensed by the load cell, which moves up to a fixed distance of 50mm. The variation of force verses distance encountered during this time is generated by suitable software that is connected to the machine via a computer.

There were three tests carried out with constant currents each time of 0A, 0.2A, and 0.4A respectively.

B. *Results*

Table.1 Results table obtained from experiment

Current	Ultimate Force
0	14.06
0.2	21.57
0.4	30.00

After applying the power law to the above results, we derived a governing equation, which relates the damping force as a function of the applied current;

$$F= 43.108\, I^{1.085} + 14.06$$

Where; F=Damping force (N)
I=Applied current (A)

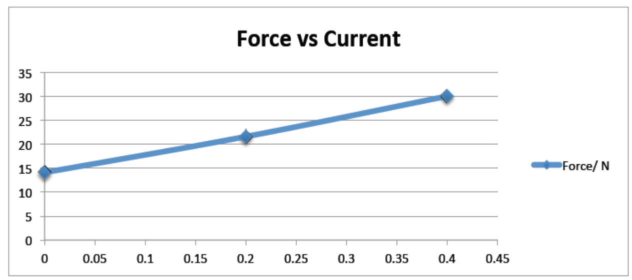

Fig.9 Force vs. current graph.

From the above graph, it is seen that as the applied current is increased from 0A to 0.4A, the damping force also increases from an initial reading of 14.06N to 30N.

The graphs relating the damping force to the piston travel are given in the appendix, which depicts the behavior of the damping force with the piston movement within the cylinder. It can be seen that, as the piston traverses towards the midpoint of the coil region the damping force increases, due to increased magnetic flux intensity within the region.

VI. CONCLUSION

After summation of all the data and results obtained patent to MR fluids, we have come to a conclusion that when the current (I), through the coil around the fluid is increased, the viscosity of the fluid increases, which comes about as the iron particles within the fluid align themselves with the field lines and form a semisolid or Bingham plastic, providing better damping properties, which in---turn leads to increased damping.

MR fluids being a Non---Newtonian fluid, acts as a smart fluid whose viscosity varies with magnetic flux, which increases its application based functionality in vast industries and with high efficiency. The MR fluids main features are: fast response, simple interface between electrical power input and the mechanical power output, controllability and integration in complex system, which provides for a reliable technology in the engineering and medical field based applications.

Finally it stands that the experimental feedback walks hand in hand with the theoretical description, and our modified suspension is a working model of the real scenario, and can be implemented with the help of a few circuits.

ACKNOWLEDGMENT

Firstly we would like to thank the institute; CSPIT, CHARUSAT, for providing us with the platform and medium through which we magnified our intellectual levels. We are highly indebted to Mr. Kalpesh Vaghela (Assistant Professor) and MR. Dipal Patel (Assistant Professor) for their guidance, supervision, providing necessary information regarding the project and for their support in the project. Along with them, we want to extent our gratitude to DR. RV Upadhay (Principal---PDPIAS), for enriching our knowledge on the project, and providing the Magneto-Rheological Fluid

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