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DEVELOPMENT AND TESTING THE PERFORMANCE OF MAGNET ORHEOLOGICAL DAMPER FOR VEHICLE SUSPENSION SYSTEM

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ABSTRACT
The work is focused on the study of theproperties of Magneto-rheological (MR) fluid and also the performance of MR damper for different current ratings. The work comprises of the preparation of magneto-rheological fluid for the MR damper, magnetic coil design, testing the property of MR fluid (flux density) and also the characteristic of MR damper.A magneto rheological fluid is a very useful constituent material for the engineers which are involved in the design of brakes, damper, clutches and shock absorber system. Now a day, the increasing costumers demand leads into the development of a damper for the suspension system which provides a variable damping according to the road condition. To improve the ride comfort the smart materials like MR fluid, Electrorheological fluid and Piezoelectric material are generally used in the dampers. The MR fluids are good in terms of strength, controllability, dynamic range and having low power consumption. Hence the MR fluid is selected for the study.

KEYWORDS: MR (Magnetorheological), Magnetic flux,MR damper .

I. INTRODUCTION

Magnetorheological fluid
The discovery of Magneto Rheological (MR) fluid is attributed to Jacob Rabinow in 1940's. Magneto rheological fluids are a class of controllable fluids which can be simply referred as a smart material. Nowadays they are stable exhibit many attractive properties such as high yield stress and low viscosity. Because of this magneto rheological fluids are recently used in suspension of high class vehicle. Magneto rheological fluids are mixture of micron sized ferromagnetic particle and grease in appropriate carrier oil. MR fluids manifest a change in rheological properties on the application of external magnetic field. Rheology is branch of science that deals with the study of deformation and flow of matter such as magneto rheological fluids, blood, paint etc. under the impact of a stress. The rheological property of controllable fluids turns on properties of the carrier oil, attention and density of particles, particle size and shape, external magnetic field and temperature etc.
The typical properties of magneto rheological fluids are as shown in Table 1.

Table 1: Properties of MR fluid

Property	**Range**
Density	3 - 4.5gm/cm^3
Initial viscosity	0.2 – 1.0 (Pa.s) at 24^{0}C
Magnetic field strength	160 – 240 (KA/m)
Maximum yield stress	50 – 100 (KPa)
Reaction Time	10 – 20 millisecond (ms)
Stability	Good
Working temperature	-50^{o}C to 150^{0}C
Supply voltage and current	12V and 0.1 – 2A

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Basically MR fluid can be works on the three modes according to applications. These three modes are as follows:

- Flow mode
- Direct shear mode
- Squeeze mode

As per the applications these above modes are used such as flow mode can be used in shock absorber and damper, direct shear mode is useful in brakes and clutches, and squeeze mode is used for controlling small movements with large force.
For the application of magneto rheological damper flow mode can be used as follows:

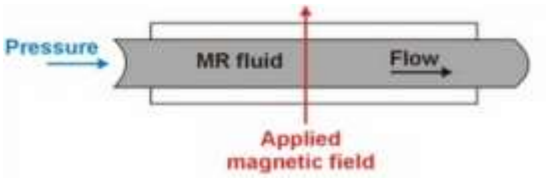

Fig. 1. Flow mode of MR fluid

In flow mode fluid is presents between two stationary walls referred as north and south poles. The flow of fluid can be controlled by applying external magnetic field perpendicular to stationary walls as shown in fig. 1. The magnetizable iron particles are typically micron sizes which are suspended within the oil. In this study low viscosity paraffinoil is used to prepare the MR fluid. The iron particles are distributed randomly in normal condition that is before applying magnetic field as shown in below figure 2. At this state MR fluid act as a free flowing fluid that is it travel in any direction.

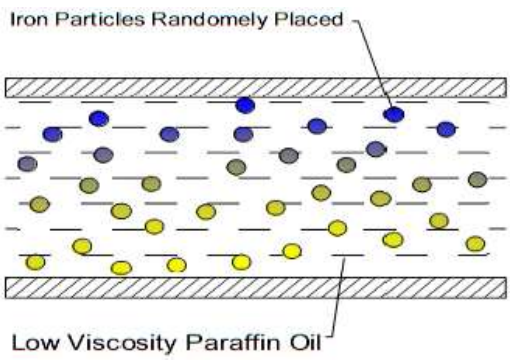

Fig. 2 Before applying magnetic field

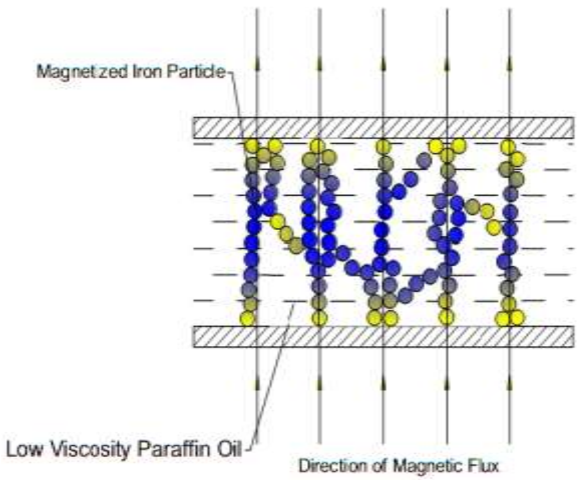

Fig. 3 After applying magnetic field

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As the magnetic field is applied to fluid, the micron size particles align themselves along line parallel to the direction of magnetic flux as shown in the figure 3. In case of magneto rheological damper fluid travels from lower chamber to upper chamber and vice versa form the passage grooved on the periphery of piston.

Figure 3 shows the actual image of MR fluid after applying magnetic field. As soon as the current passes through the coil the iron particles in the fluid attracted towards coil and arranged in rows. This action blocks the passage and resists the flow of fluid from lower chamber to upper chamber in MR damper which increases the stiffness of damper.

Fig.4Actual schematic of MR fluid after applying magnetic field

II. PREPARATION OF MR FLUID

Constituents of MR fluid

As per the application of MR fluid, formulation will be depends

Carrier oil	**Magnetic**	**Additives**
Low viscosity paraffin oil	Electrolytic iron powder	Grease
Silicon oil	**1.** Iron alloy	
water	**2.** Nickel alloy	Arabic gum

For the preparation of 100ml MR fluid following constituents are required with specified quantity as follows:

Constituents	**Quantity**
Low viscosity paraffin oil	68ml
Iron particle (50 microns)	112.32gm
All purpose grease (AP3 grease)	6.75gm

As per the requirements of MR fluid these above quantity will be changes.For preparation of 'X' ml MR fluid each quantity of constituents should be multiplied by$\left(\frac{X}{100}\right)$factor.

For the preparation of MR fluid two accessories are required as mechanical stirrer and beaker with above constituents. Following are the steps for preparation of MR fluid.

1. First take the low viscosity paraffin oil and all purpose grease (AP3 grease) with correct quantity in a beaker.
2. Stir this improper mixture of low viscosity paraffin oil and grease with the help of mechanical stirrer for proper mixing.
3. Then wait for 2hrs so that grease gets completely soluble in paraffin oil.
4. After that add iron particles of 50 micron size in above mixture and again stir it with the help of mechanical stirrer for 15 to 20 min. for proper mixing.

In the preparation of MR fluid AP3 grease is added into low viscosity paraffin oil to avoid settlement of iron particle.

III. MR FLUID TESTING

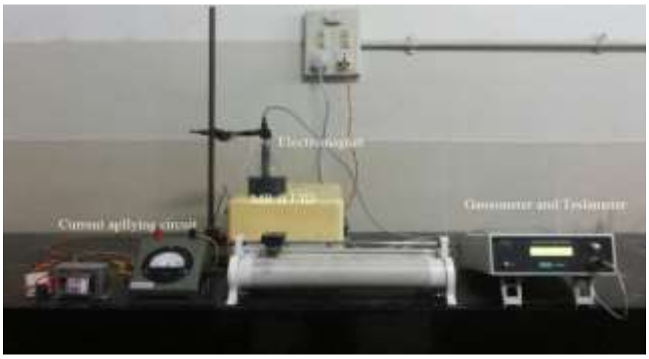

Fig.5 Experimental setup

Figure 5 shows an experimental setup for testing the MR fluid. For the testing of MR fluid following instruments are required.

1. Guassmeterand teslameter
2. Electromagnet

Guassmeter and teslameter is a magnetometer that used to measure the strength of magnetic field measured in units of gauss and teals respectively. The electromagnet is a device of electrical winding wounded on a core in which magnetic field is produced by applying external electric current. This electromagnet is used to magnetize the iron particle present in a MR fluid.

The following resultsare obtained while testing the MR fluid.

Table 1: Magnetic Field intensity corresponding to current

Current (A)	Magnetic field intensity in gauss
0	0
0.2	6
0.4	11
0.6	15
0.8	19
1.0	23
1.2	28
1.4	33
1.6	38
1.8	42

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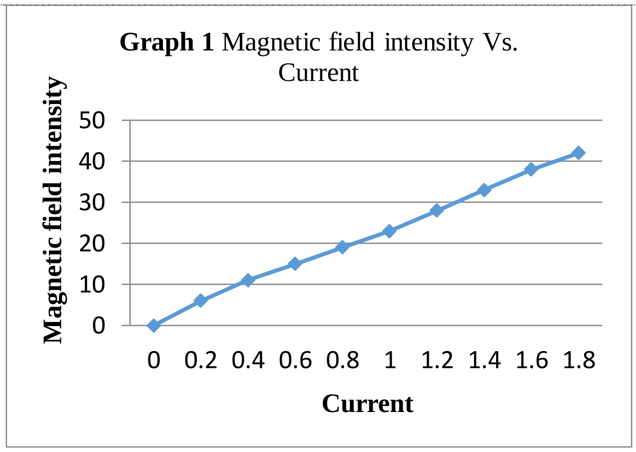

As current increases the magnetic field intensity also increases. In other words the current is directly proportional to magnetic field intensity. The graph 1 shows that magnetic field intensity is directly proportional to current.

IV. MAGNETIC CIRCUIT OF MR DAMPER

In the design of magnetic circuit for MR damper it should be assume that the magnetic loop is formed only in magnetic material and magnetic flux leakages are negligible. The actual magnetic circuit for MR damper is as follows:

Fig. 6 Magnetic circuit of MR damper

In designing of actual magnetic circuit creating an electromagnet is a major task of concern. To create an electromagnet for MR damper, the bobbin of piston is wounded by super enamel copper wire of 26 SWG that is 0.040386mm diameter. The maximum possible area for winding is decided by trial and error method and also by considering all manufacturing aspects of MR damper. Based on this data the maximum number of turns (N), possible on piston is calculated, which came out to be 280 turns. The magnetic flux (Ø) and magnetic flux densities (B) are given as:

$$B = \frac{\mu_0 I}{4\pi r^2}\oint dl$$

$$B = \frac{\mu_0 I}{2r}$$

Ø = BA
Where
B = Magnetic flux density
μ_0 = Permeability of the medium (4π*10^ (-7))
Tesla-m/A
R = Radius of bobbin
I =Supplied current
Ø = Magnetic flux
A = C/S area of bobbin

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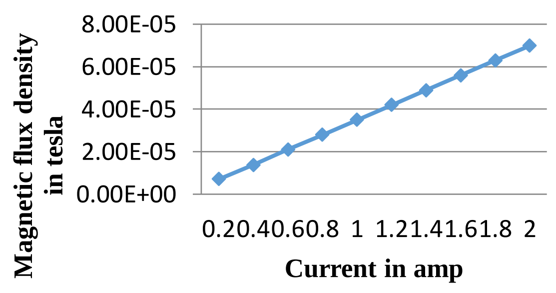
Following table shows the reading of magnetic flux density for various current which can be calculated by above formulas

Table 2: Magnetic flux density corresponding to current

Current (I)	Magnetic Flux Density (B)
0.2	6.98132E-6
0.4	1.3693E-5
0.6	2.094E-5
0.8	2.7925E-5
1.0	3.4907E-5
1.2	4.1887E-5
1.4	4.8869E-5
1.6	5.5851E-5
1.8	6.2832E-5
2.0	6.9813E-5

The graph 2 of magnetic flux density vs. current is plotted as follows and which must be a straight line. The graph shows that magnetic flux density is directly proportional to current.

Graph 2. Magnetic flux density Vs. Current



V. MAGNETO RHEOLOGICAL DAMPER

Dampers are an integral part of any suspension system. Magneto rheological damper is the assembly of piston and cylinder with electrical winding placed on periphery of the piston bobbin. The two terminal of electrical winding are carried out through piston rod. The electrical winding produces magnetic field when the current is passed through it. There are 4-6 holes grooved on periphery of the piston bobbin to allow MR fluid passing from lower chamber to upper chamber and vice versa.

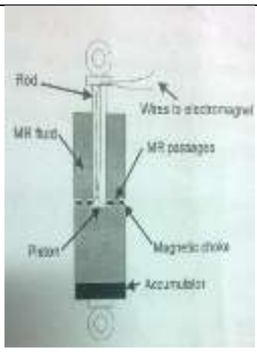


Fig.7 Schematic of the MR damper

Fig.8 Photo of the MR damper

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When the current is passed through the electrical winding it produces magnetic field. Because of that MR fluid gets magnetizes and iron particles align themselves along a line parallel to the direction of magnetic field. The micron size iron particle gradually blocks the flow of MR fluid from lower chamber to upper chamber by gradually increase in current and we get desired damping that means the shock are absorbed by MR damper.

VI. TESTING OF MR DAMPER:

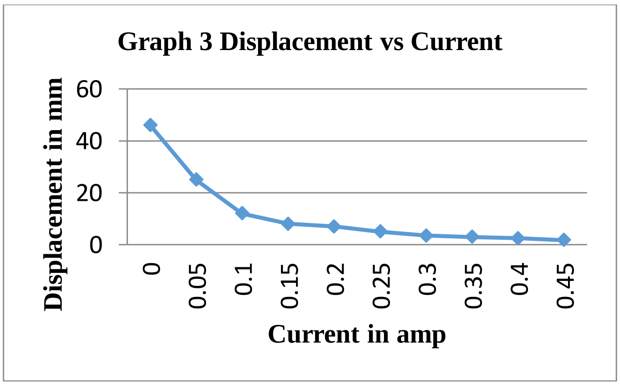
The testing of MR damper is carried out on a universal damper testing machine as follows:

Fig.8 Experimental setup for MR damper testing

The test is conducted to check the displacement of damper at different current by keeping the load constant. The following results are obtained from the test.

Table 3: Displacement for various current

Current (A)	Displacement (mm)
0	46
0.050	25
0.100	12
0.150	8
0.200	7
0.250	5
0.300	3.5
0.350	3
0.400	2.5
0.450	1.7



The above graph shows that if the current to electrical winding increases gradually the displacement goes on decreasing.

VII. CONCLUSION

The aim of this work was to prepare a MR fluid and study the properties of the same and also to develop a MR damper. From the results obtained it was concluded that the MR damper offered superior damping properties over a wider current range. It also eliminated the need to compromise between ride comfort and handling which is a major drawback with the present passive suspension system. The low cost MR fluid prepared will have a wider application in more economical vehicles making this technology available to everyone around the globe, which right now is restricted to a few expensive vehicles

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