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Investigation of Various Parameters in Magneto-Rheological Dampers

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Abstract: ***Automobile industry and magneto-rheological dampers are now a new area of research. Magneto-rheological mufflers utilize the energy generated by magnetic fields, and scientists have initiated a re-consideration of new damping systems. The suspension system based on magneto-rheological fluid in modern era is becoming an intelligent system with superior properties such as strength, controllability, range, response time, energy utilization, structure etc. In magneto-rheological dampers number of required components are too less which leads to cost effective suspension. In this exploration, a magneto-rheological damper was fabricated, and experimental study had been performed. The magneto-rheological damper's construction cost is not as much since it doesn't have intricate components. The modern enquiries the consequences of magnetic field/current on applied load, yield stress, and stress developed in suggested magneto-rheological dampers. The experimental results illustrate the effect of external load, yield stress, & stress generated in suggested dampers depends on magnitude of current/magnetic field. The experimental investigation also demonstrates that magneto-rheological dampers work at a specific threshold magnetic field substandard to critical value of a magnetic field, magneto-rheological fluid reposes in a liquid phase. The threshold magnetic field and mechanical properties are inter-related with each other in magneto-rheological based dampers.***

Keywords: ***Magnetic field, Stress, Load, Magneto-rheological Fluid, Damper***

I. INTRODUCTION

Magneto-rheological fluid has its place to smart materials, conceived in late 1940s by Rainbow that signify a functional magnetic field with changes in rheological behavior. MR fluids are suspensions of micron-sized dispersed magnetic phase in a non-magnetic carrier continuous phase along with additives. Rheological properties i.e. elasticity, plasticity, or viscosity change due to magnetic field, magneto-rheological fluid consists of spineless particles by diameter range from one to five mm with water, mineral oil and glycol as a carrier [1]. The outcome of magnetic field vicissitudes the state from liquid to semi solid of magneto-rheological fluid.
The diagram specified underneath will help you in help to understand relation of magnetic field and magneto-rheological fluid more clearly.

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As one can see, in figure 1(a), in absence of magnetic field micro/nano iron particles are loosely packed in magneto-rheological fluid. However, the concentration per unit volume is constant throughout the fluid. A suitable intensity of magnetic field (around 0.3T to 1.6T for our experimental analysis) is brought together, revealed in figure 1(b), the iron molecules align themselves in various chain like structures within the fluid, due to the layout between these iron particles is reduced drastically and their force of attraction is higher to each other, causing the liquid to develop a semi-solid like shape, as a whole. [2,3]

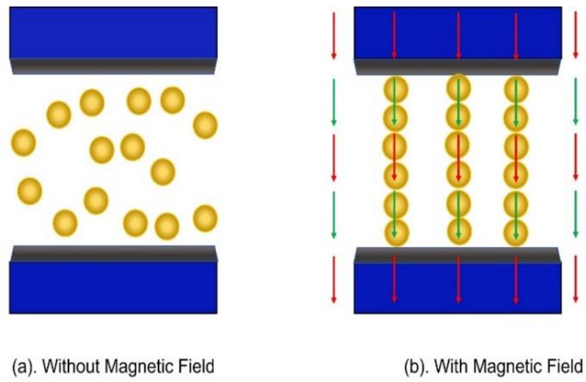

Fig.1 Behaviour of Micro/Nano Iron Particles

Magnetic rheological dampers are more commonly called MR dampers. They are intelligent dampers and used to control vibrations in suspension systems. Computational and experimental approaches are being used to analyze the MR damper [4, 5]. The vehicle ride quality had direct relation with automobile suspension system. The generally used hydraulic system is partially capable to adjust real-time performance in road conditions. But magneto-rheological fluids fulfill all time-based requirement as and when required. It is vital & prerequisite to mature an intelligent automobile suspension which can control real-time performance & with suitable adjustment. MR dampers in modern era are dominating vibration controllers in the field of intelligent suspension presently, because they provide better controllability, response rate, low energy, with reduced number of parts and simple structures. MR fluid basically works on three approaches, which are valve, shear and squeeze approach respectively. In MR damper and shock absorber based on value mode, MR fluid flow among two immobile plates i.e. cylinder. In this work a simple cost-effective MR damper is designed and developed by selecting appropriate parameters. Parametric study for instance critical load, current, field intensity and yield stress of MR-fluid has been performed.

II. DIMENSIONS AND SPECIFICATIONS:

A simple prototype model of MR damper has been fabricated. The model is economical and straightforward without considering any blueprint factors in MR damper design. Capacity of such type of MR damper affects marginally for small conversion to magnetic field. The dimensions of piston cylinder, magnetic staple are listed in tabular form, table 1 to table 3.

Table 1: Piston Specifications

S. No	Piston Component Name	Dimension
1	Piston head diameter	47 mm
2	Stroke length	55 mm
3	Piston rod diameter	20 mm
4	Length of piston rod between steps	60 mm
5	Maximum load applied on piston	30 Kg

Table 2: Cylinder specifications

S. No	Cylinder Component Name	Dimension
1	Inner diameter	50 mm
2	Outer diameter	60 mm
3	Height	200 mm

Table 3: Electromagnet Specifications

S. No	Electromagnetic Component Name	Dimension
1	Core length	60 mm
2	Core diameter	20 mm
3	Wire used for windings	21 AWG copper wire
4	Number of turns	4000
5	Current range	0-6 A

i). Piston specifications:

Type- Two steps
Piston head diameter= 47mm
Stroke length= 55mm
Piston rod diameter = 20mm
Length of piston rod between steps= 60 mm
Material used is Cast iron.
Altogether the dimensions of piston are based on the hypothesis, concentrated capacity that can be applied on piston is 30kg.

ii). Cylinder specifications:

Inner diameter= 50 mm
Outer diameter = 60 mm
Height = 200mm
Material used is cast iron

iii). Electromagnet specifications:

A magnetic field strength of 0.1T is required for the experiment to work effectively. The strong point of the electromagnet depends upon the turnings along the piston, the current supplied and the permeability of the material.
Piston rod is taken as the core of electromagnet.
Core length= 60mm
Core diameter= 20mm
Wire used for windings= 21 AWG copper wire.
Number of turns = 4000
Current range = 0-6 A

iv). DC Supply voltage circuit

For 24V DC supply circuit design, AC supply is connected to a step-down transformer of 24 volt AC output. The AC voltage is converted to DC by a rectifier and the voltage is controlled from 0V to 24V by a regulator.
The components used in the set- up are shown in figure 2, figure 3 and figure 4. Other components are mirror, laser light, support structure.

Fig 2. Piston

Fig 3. Piston-Cylinder

Fig 4. Electromagnet

III. EXPERIMENTAL SET UP

The experiment is executed by developing a piston-cylinder mechanism. The fluid was chockfull between cylinder and piston. The movement of piston in reciprocating direction depends upon various parameters, the parameters which dominant movement are current, magnetic field, piston, cylinder, electromagnetic etc. A schematic line diagram showing working of MR damper and actual setup has been shown in figure 5 & figure 6 respectively.

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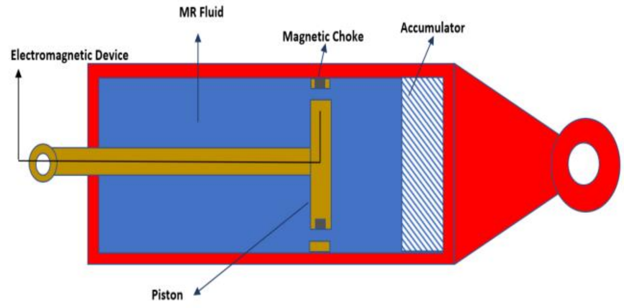

Figure 5: A schematic line diagram of MR damper

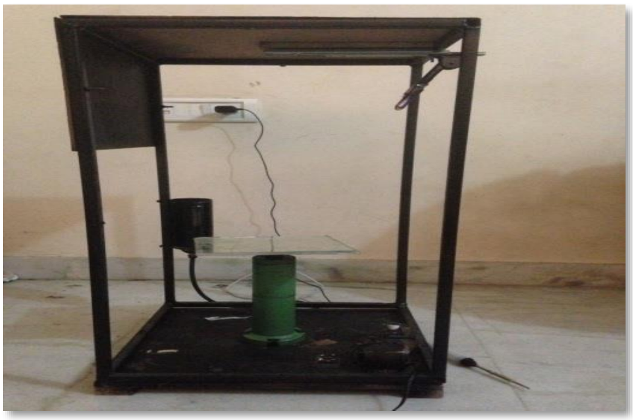

Figure 6: Experimental set up of MR Damper

All the components of the experimental arrangement were finally assembled. A main housing was constructed to protect the instruments inside it. The housing consists of a laser ray organization on one sideways at the top and on opposite side; a wooden board is present where the screen or graph is placed. An arrangement was made to support a mirror on top side of piston rod. The laser pointer projects the ray onto the mirror surface, from where it is reflected and is depicted on the screen or graph provided. The tenacity of this arrangement is that by way of the piston moves, the deflection caused due to the loading of weights on the mirror surface also moves. The lowermost in main housing consists of a cylinder piston arrangement, step down transformer and regulator. In the developed model, the parametric study for instance critical load, current, field intensity and yield stress of MR-fluid is performed. Due to feasibility of selecting parameters, one can believe that further research is vital and wished to do so by studying certain properties and hence, concluded that the major objectives of this research are, to plot a graph among critical load and current, plot a graph to relate applied magnetic field intensity and yield stress of MR fluid, plot a graph between applied force (load) & strain of MR fluid (at constant magnetic field), plot a graph to relate shear strain ratio and shear stress (at constant magnetic field). Study will be a milestone for selecting appropriate limits for MR damper design and development.

IV. BASIC EQUATIONS

The basic equations on which magneto-rheological fluid work are-

Yield stress, $Y = mg / A$,

A= Area of Cross section

$Area = \pi / 4D^2$, where D, internal diameter of the cylinder is 50.00 mm.

Magnetic Field Intensity, $H = (IN) / L$,

where I is current in amperes, L is average length of magnetic circuit (60 mm) and N are the integer of (4000). H be in kilo amperes per meter.

Applied load vs. strain at constant magnetic field intensity

$$Strain = \frac{\Delta L}{L}$$

ΔL=change in length (distance travelled by piston)

L=original length (initial height of the fluid)).
L (height of fluid) is fixed, i.e., 70 mm.

Distance travelled by piston = $x \tan\theta$
Where θ is the angle of incidence on the mirror and can be measured using protractor.
x is the distance between centre of mirror and edge.
Relation between Shear strain & shear stress
Using above three trials alongside with the formula,

$$\tau = \tau_o \gamma + \mathrm{sign}(\dot{\gamma}) + \eta \dot{\gamma}$$

Viscosity at constant magnetic field is 1 Pa.Sec
τ = shear stress , τ_o = Yield stress , γ = strain , η = viscosity
The strain rate is calculated using the above-mentioned formula.

V. RESULTS AND DISCUSSION

In the developed MR damper, the relationship between critical load versus current, yield stress versus current and applied load versus current have been investigated. The experimental analysis is done using the parameters, in which current fluctuates in the middle of 0 to 6 A, magnetic pitch fluctuates from 0.09 T to 0.12 T, wire used in binding was copper, DC voltage varies from 16 V to 24 V etc. MR damper consumes magnetic energy and increase intermolecular bonding between molecules of magneto-rheological fluid, so that semi solid/liquid phase of magneto-rheological change into solid phase. Figure 7 shows variation of current versus critical load by considering magnetic field 0.09 T, 0.10 T and 0.12 T respectively. In this experimental procedure some load is applied on piston and a laser has been concentrated on the screen. Initially current is set at maximum and piston is compressed slowly till first deflection in setup is detected, similarly other reading are also noted using the same procedure. It is revealed that magnetic field has direct impression on critical load, its magnitude increases with the increase in current. It can be concluded that critical load increases with current but after a threshold value of current, deviation in critical load is negligible.

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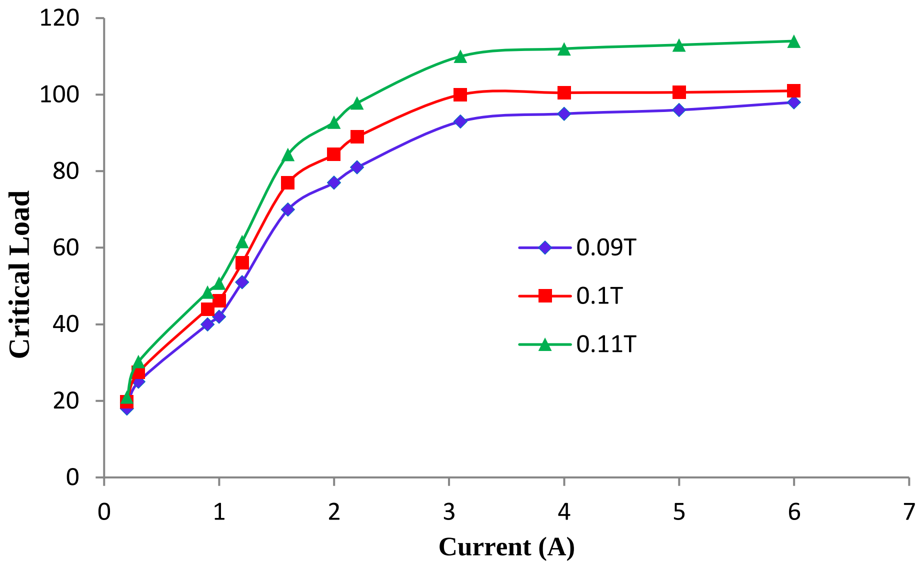

Figure 7: Variation of Critical Load With Current

Figure 8 demonstrates deviation in yield stength in contradiction of magnetic field for unlike values of DC volts. In this diagram three different voltages have been considered, these voltages are 16 V, 20 V, and 24 V respectively. The outcome achieved by experimental analysis demonstrates that yield stress is associated with the magnetic field. The outcomes in figure 8 also indicates that after certain value of magnetic field, yield strength is observed to be constant for particular dimensions of MR damper. In MR damper yield point is the parameter when damper attain maximum velocity for a specific type of damper. The value of critical yield strength depends upon lots of parameters, some factors are: MR damper dimensions, type of magneto-rhelogical fluid etc. Figure 9 elaborate variation of applied load versus strain of MR damper for different values of magnetic field. In this experiment the strain of MR damper varies in the middle of 0 to 0.7. The value of applied load varies from zero to 120 N, applied load initialy varies almost straight line from 0 to 0.3 and than increased in huge amount from 0.3 to 0.7. For given parameters the maximum value of applied capacity is 120 N when strain is 0.7 for magnetic magnitude is 0.12 T.

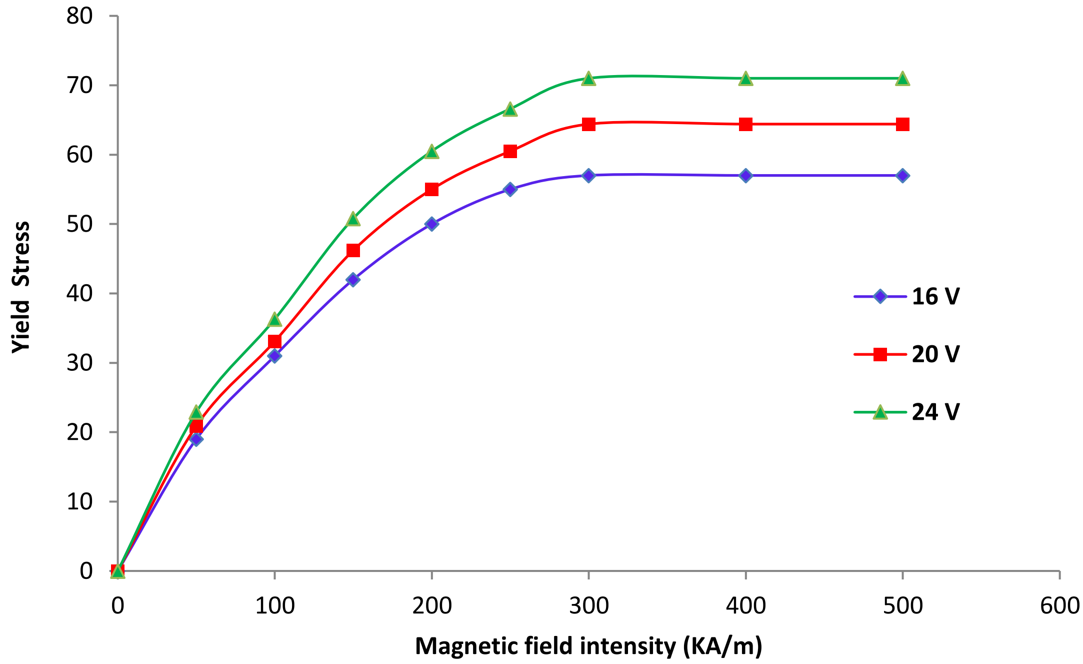

Figure 8: Variation of Yield Stress With Magnetic Field Intensity

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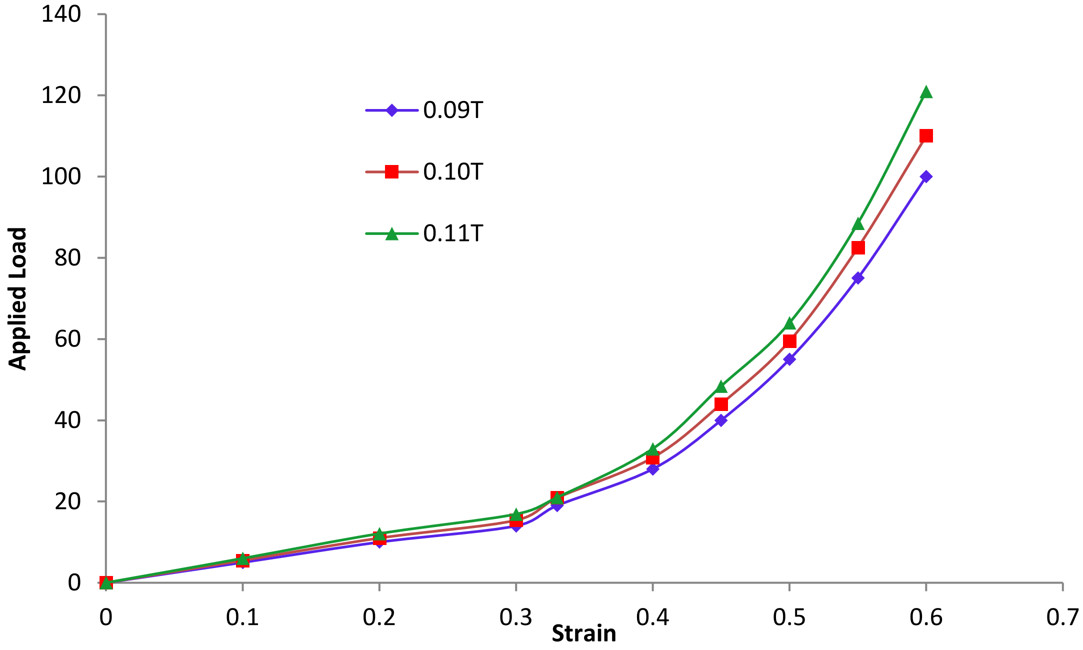

Figure 9: Plot of Applied Load Vs Strain

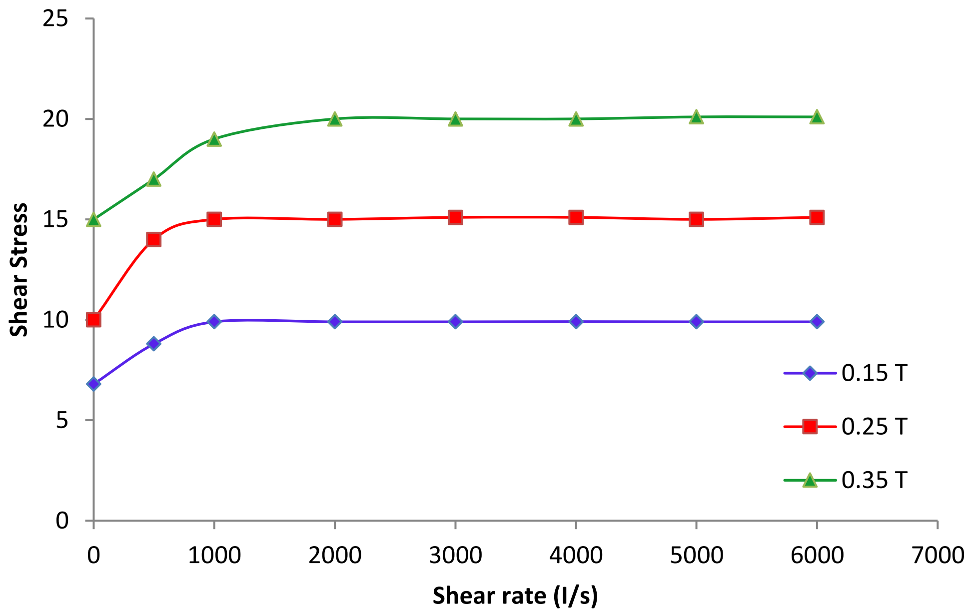

Figure 10: Plot of Shear Stress Vs Shear Rate

From the fig 10, it can be analysed that the peak of MR fluid surges with magnetic field strength at non-uniform rate. The rate of increasing shear stress with magnetic field intensity drives on shrinking and at a certain magnetic arena greatness capacity point has come; further increase in magnetic field intensity will show no effect on shear stresses in MR fluid.

The results reveal that the strain in MR fluid at constant magnetic field propagates and increase with applied load and the rating of developing strain is also increased. At a certain load slant in graph becomes infinity which express that the auxiliary increment in load will have no effect on strain. The results obtained reveal the complete behaviour of MR fluids.

VI. CONCLUSIONS:

A comprehensive study on MR damper has been investigated. In the investigation performed it has been established that yield stresses of MR fluid has growth with escalation in magnetic pitch intensity at non-uniform degree, but afterward certain critical value of magnetic field adjustment in yield strength is negligible. The percentage of strain and shear force likewise depends upon magnitude of external applied load.

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The result obtained by current study shows that the MR damper can be effectively used in automobiles as shock absorber and mitigate accidents occurrence due to sudden speed breaker and ditch/pit on road.

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