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Research Article

Typical Experimental Design & Testing of Model MR Damper using Helical coiled spring

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Abstract

A magneto rheological damper or magneto rheological shock absorber is a damper filled with magneto rheological fluid, which is controlled by a magnetic field. This project addresses a model design of mr damper by using a normal helical spring for different mr fluid conditions; the research project speaks about the condition of normal helical spring in displacement which being used in mr damper and also will be compared for its displacement analysis at normal state of loading without damper. The work outs of this project are completely used to suggest the designers of mr dampers while selecting a helical coil spring and mr fluids, in fact they are as their essential elements in design.

Keywords: *Magneto rheological fluids, Carbonyl particles, NI LABVIEW software, LVDT sensor & load cell*

Introduction

A typical MR fluid consists of 20-40 percent by volume of relatively pure, 3-10 micron diameter iron particles, suspended in a carrier liquid such as mineral oil, synthetic oil, water or glycol. Varieties of proprietary additives, similar to those found in commercial lubricants to discourage gravitational setting and promote particle suspension, are commonly added to MR fluids to enhance lubricity, modify viscosity and inhibit wear. Iron particles in suspension align and develop yield strength in the presence of a magnetic field. The change from a free-flowing liquid to a semi-solid when a magnetic field is applied is rapid and reversible. 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 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.

Design of MR Damper

Cylinder Dimensions

Outer Diameter - 48.12mm
Inner Diameter - 42.35mm
Length - 30cm

Flat Plate Dimensions

Diameter - 48.12mm

Spring Dimensions

Outer Diameter - 30mm
Inner Diameter - 24mm
Height - 44mm
Number of Coils - 5
Coil Diameter - 3mm
Height – 0.5mm

Specifications of the Helical coil spring used in the Damper design

Metal of the spring= carbon steel (**oil tempered**)
Diameter of the spring wire d=2.30 mm
Outer coil diameter Do = 29.9 mm
Inner coil diameter Di = 25.25 mm
Mean diameter D = (Do-d)

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= 29.9-2.3
=27.6mm
Length of the spring (free) L = 44 mm
Number of coils in the spring n = 0.05 turns
Pitch of the spring p =11 mm
Stiffness of spring = 2.6 N/mm
= 2.6*103 N/m^2
Elastic modulus E = 210 KN/mm^2
Modulus of rigidity of spring G (or) C = 80KN/ mm^2

Copper Winding

Gauge of Wiring - 36
Number of Turns - 1300

Piston Dimensions

Outer Diameter - 34mm
Length - 80mm

Piston Rod Dimensions

Length - 180mm
Diameter - 20mm

Carbonyl Iron Particles

Molecular Weight - 55.85
Mass density of iron powder - 7.8 gm/cc
Solid particles - carbonyl iron particles

Fig: MR Damper cylinder

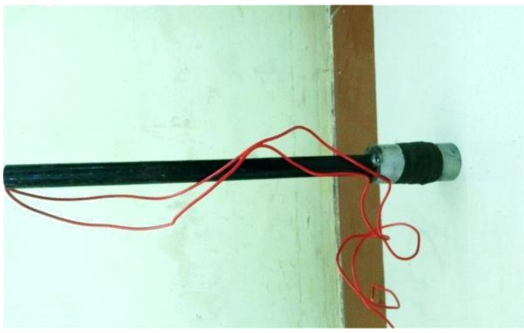


Fig: Piston and copper wire assembly

Fig: MR Damper helical spring

Fig: Carbonyl iron particles

Magneto rheological fluids used in design

Typical magneto rheological fluids are the suspensions of micron sized, magnetizable particles (mainly iron) suspended in an appropriate carrier liquid such as

Silicon Oil

Viscosity (25c) - 332.5 to 367.5 cs
Specific Gravity - 0.966 to 0.972
Refractive Index - 1.4025 to 1.4045
Flash Point - 600F
Acid Number - max 0.01
Volatile Content - max 0.5%
Water - 0.3%

Ethanediol (Ethylene Glycol):

Molecular Weight - 62.07
Assay - min 99.0%
Wt. per ml at 20c - 1.112 to 1.115g
Maximum limit of impurities
Iron - 0.0002%
Acidity - 0.1 ml N%

Fig: MR Fluids Silicon oil and Ethylene Glycol

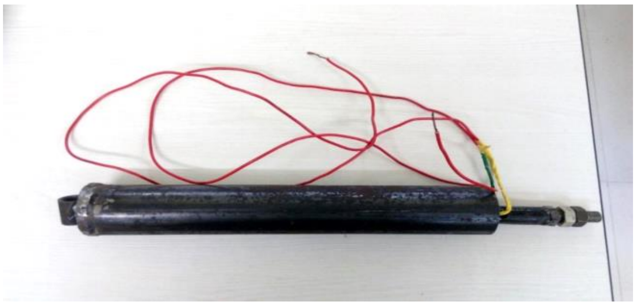


Fig: Assembly of MR Damper

Experimental Setup

The experimental setup consists of Regulating Power Supply (RPS), LVDT sensor, Load cell, NI- DAQ and MR Damper. All these apparatus are assembled in sequence by a circuit as shown in figure.

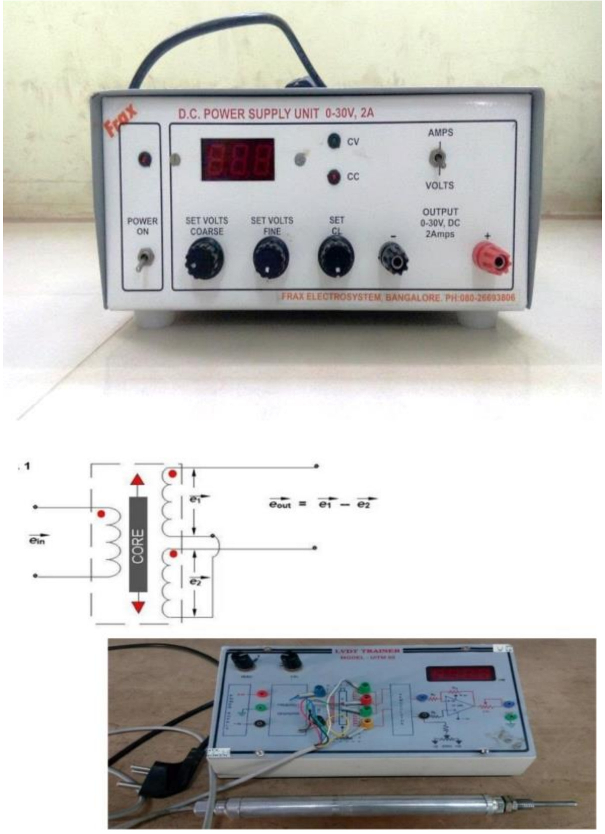


Fig: RPS & LVDT

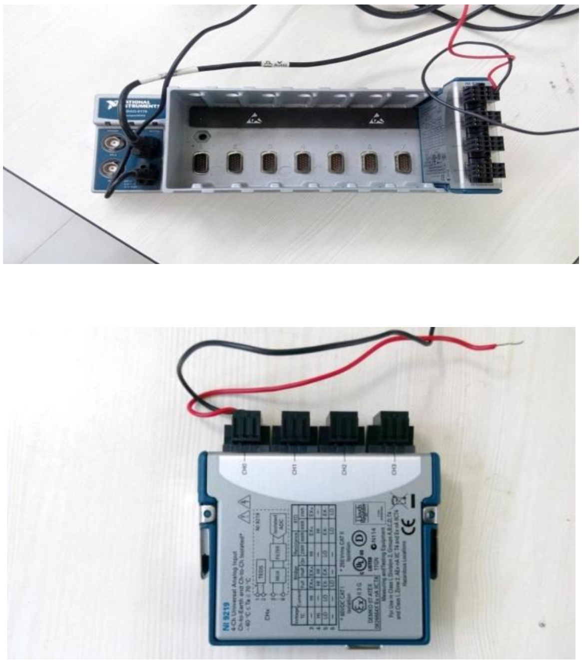
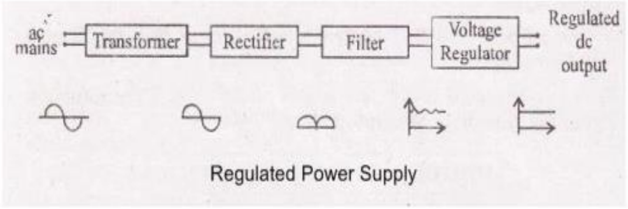


Fig: NI DAQ & NI 9219

Construction and working of Regulated Power Supply

The general block diagram of regulated power supply is shown below



The LVDT converts a position or linear displacement from a mechanical reference (zero, or null position) into a proportional electrical signal containing phase (for direction) and amplitude (for distance) information. The LVDT operation does not require an electrical contact between the moving part (probe or core assembly) and the coil assembly, but instead relies on electromagnetic coupling.

DAQ is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure with a computer. A DAQ system consists of sensors, DAQ measurement hardware and a computer with programmable software and converting the result samples into digital or graphical or pictographically values that can be implemented by a computer. DAQ typically converts analogue waveforms into digital values for easy processing.

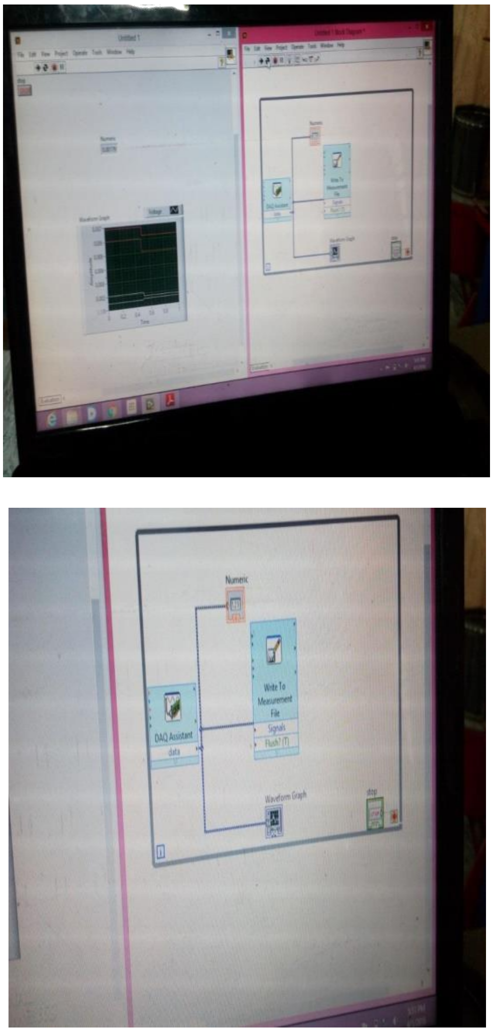


Fig: NI LAB VIEW software and DAQ circuit diagram

Results: Ni DAQ Result for Silicon Oil as Mr Fluid for Uni Load Condition

	A	B	C	D	E
1	**voltage**	**avg time**	**time**	**displacement**	**load**
2	0	11.26315	26.514	**0.066410731**	0.002238105
3	2	13.36842	50.034	0.067362535	0.002235
4	4	12.42105	73.693	0.066975	0.002237
5	6	10.8421	97.168	0.067533	0.002235
6	8	12.05263	121.795	0.065388	0.002231
7	10	12.78947	145.875	0.065203	0.002231
8	12	10.89473	169.356	0.065094	0.002228
9	14	12.63157	193.142	0.065054	0.002228
10	16	11.8947	216.928	0.065056986	0.002223512

Results: NI DAQ Result for Silicon Oil as Mr Fluid for Double Load Condition

	A	B	C	D	E
1	**voltage**	**avg time**	**time**	**displacement**	**load**
2	0	12.6315	26.475	**0.065969**	0.002234
3	2	12.6315	52.691	0.0660077	0.002235
4	4	12.26315	77.001	0.065481	0.002236
5	6	12.9473	103.335	0.066111	0.002235
6	8	11.78947	127.583	0.065858	0.002235
7	10	12.36842	154.28	0.065673	0.002228
8	12	13.68421	181.282	0.065234	0.002221
9	14	12.15789	205.648	0.065662	0.002219
10	16	11.52631	229.302	0.066134	0.002224

Results: NI DAQ Result for Ethylene Glycol as Mr Fluid for Uni Load Condition

	A	B	C	D	E
1	**voltage**	**avg time**	**time**	**displacement**	**load**
2	0	10.05263	29.17	**0.0663404**	0.00223541
3	2	10.7368	52.531	0.066488785	0.002237251
4	4	11.05263	107.481	0.066707209	0.002237109
5	6	14.5784	162.16	0.066549358	0.00222762
6	8	10.6315	184.903	0.066355966	0.002224362
7	10	10.6315	207.732	0.06604544	0.002223654
8	12	10.26315	228.43	0.066093392	0.002220963
9	14	11.3684	251.293	0.066081668	0.002219263
10	16	9.5789	271.406	0.065989144	0.002220963

Results: NI DAQ Result for Ethylene Glycol as Mr Fluid for Double Load Condition

	A	B	C	D	E
1	**voltage**	**avg time**	**time**	**displacement**	**load**
2	0	12.3684	23.325	**0.6676641**	0.002238384
3	2	10.8421	45.983	0.067083	0.002237
4	4	11.0526	70.531	0.06684	0.002238
5	6	13.421	96.022	0.067023	0.002231
6	8	11.6842	119.831	0.066924	0.002241
7	10	10.1052	145.41	0.066653	0.002242
8	12	12.36	171.191	0.066373	0.002239
9	14	13.3157	198.267	0.065781	0.002231
10	16	11.421	221.203	0.065875	0.002237

Displacement calculation

Analysis of practical road loading conditions for a normal helical spring

Case (i): Consider load on spring as 5Kg (**F=5Kg**); as considered in experimental set up. Analysis of displacement by using assumed load (F=5Kg)

As per design standards of helical spring displacement

$\boldsymbol{\delta = 8FD^3n/Gd^4}$

Where F= load in kg =5 kg

D= Mean diameter = 27.6 mm

n = Number of coils in spring = 5 turns

d = Diameter of the spring wire = 2.30 mm

G = Modulus of rigidity of spring = 80 kN/mm^2

$\delta = (8*5*9.81*27.575^3*5) / (80*10^3*2.3^4)$

$\boldsymbol{\delta = 18.37571\ mm}$

Case (ii): Consider load on spring as 10Kg (**F=10 Kg**); as considered in experimental set up. Analysis of displacement by using assumed load (F=10 Kg). As per design standards of helical spring displacement $\boldsymbol{\delta = 8FD^3n/Gd^4}$

Where F= load in kg =10 kg

D= Mean diameter = 27.6 mm

n = Number of coils in spring = 5 turns

d = Diameter of the spring wire = 2.30 mm

G = Modulus of rigidity of spring = 80 kN/mm^2

$\boldsymbol{\delta = 8FD^3n/Gd^4}$

$\delta = (8*10*9.81*27.575^3*5)/(80*10^3*2.3^4)$

$\boldsymbol{\delta = 36.75143\ mm}$

Tabular comparison of displacement values between normal helical spring vs. MR Damper

Displacement (mm) For Mr Damper with *Silicon Oil*

Table: Displacement comparison between MR fluid Silicon oil and normal spring

SNo	Loads used in experimental work (kg)	Normal helical spring (displacement value)	MR Damper using silicon oil from results (mean displacement value)
1	**5**	**18.37571**	**0.065056986**
2	**10**	**36.75143**	**0.066134**

Displacement (mm) For Mr Damper with *Ethylene Glycol*

Table: Displacement comparison between MR fluid Ethylene glycol and normal spring

SNo	Loads used in experimental work (kg)	Normal helical spring (displacement value)	MR Damper using silicon oil from results (mean displacement value)
1	**5**	**18.37571**	**0.065989144**
2	**10**	**36.75143**	**0.065875**

Experimental permitted load in setup, for 5 kg

δ silicon = 0.065056 mm < δ normal helical spring = 18.37571 mm

δ Ethylene glycol = 0.065989144 mm < δ normal helical spring = 18.37571 mm

Experimental permitted load in setup, for 10 kg

δ silicon = 0.066134 mm < δ normal helical spring = 36.75143 mm

δ Ethylene glycol = 0.065875 mm < δ normal helical spring = 36.75143 mm

Conclusion

Meticulously the results have been speaking that, the displacement phenomenon in mr damper assembly comparably quite lower than the normal spring state under any load and under any mr fluid condition. By the results the suggestions are made in such way that; the design of mr damper inherently a work of spring and mr fluids which are to be selected very prominently. The selection of magneto rheological fluid will state the displacement work of the damper and affects the life of the spring wire material.

The designers of mr damper should come to know the basic strategies of helical spring and fluid work in the damper in order to provide cushion by their designed dampers. The work has carried out to state the displacement phenomenon of the springs used in mr damper under different mr fluids and also to compete with normal helical spring displace strategies in order to suggest the designers.

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