Modification of Classical Hydraulic damper into Semi active damper using MR Approach

L. B .Raut [1], Y.M. Khedkar [2], S.Y. Salunke [3] S.V. Jadhav[4]

[1, 2, 3, 4] Mechanical Engineering Department, SVERI's, College of Engineering, Pandharpur

DOI: 10.29322/IJSRP.9.03.2019.p8795
http://dx.doi.org/10.29322/IJSRP.9.03.2019.p8795

Abstract-
Vibration suppression can be considered as one of the most important parameter affecting the performance of Mechanical structures and related safety and comfort. To reduce the system vibration of such systems, an active vibration control mechanism is required. Generally, vibration control techniques can been categorized into passive and active. Most of the existing systems falls under the passive category. Active damping is another very useful approach, which can adjust to different loading conditions, which uses sensed structural responses to determine the control forces generated on the structure. The active vibration reduction system can reduce different vibrations modes efficiently. However, these systems require considerable amounts of external power for their working. Another type of vibration reduction system, called as semi-active control approach has been examined by several researchers. This method is observed to be having better performance than passive control and required less power than active control. Magneto-Rheological (MR) dampers and Electro-Rheological (ER) dampers are two main examples of this type. However due to various advantages of MR dampers over ER dampers, MR dampers used for more no. of applications

Keywords- Vibration, Accelerations, Semi active damper Magneto-Rheological (MR) dampers and Electro-Rheological (ER)dampers

I. Introduction

Magneto-Rheological dampers and the related devices have been under development for many years, but their commercial application started in late 2000A.D. in some expensive passenger vehicles. These Magneto-Rheological dampers falls under semi-active category. The Magneto-Rheological fluids, which are used in such devices, can change from liquid to semisolid when they come under the influence of magnetic field. These damper have many benefits like, low cost of manufacturing, quick response, ability to change the viscosity in few milliseconds, easy of construction, low operating power requirements and more effectiveness for vibration absorption. The properties of such Magneto-Rheological fluids depend on the size of particles, properties of the carrier fluid used, additives and stabilizing agents used, applied magnetic field, operating temperature, concentration and density of particles, etc. Magnetic flux density generated in the damper due electric coil is proportional to the applied filed.

The properties of the Magneto-Rheological suspension, the working mode (shear mode, flow mode or squeeze mode) and the design of the magnetic circuit consisting of Magneto-Rheological fluid, flux guide and coil considerably influence the properties of the actuator. The design of the magnetic circuit of a Magneto-Rheological fluid actuator is analyzed by finite-element-method. Yang et al. presented a Magneto-Rheological damper design methodology, which was based on the magnetic circuit design according to the requirement of adaptive structure characteristics.

II. METHOD TO PREPARE MAGNETO-RHEOLOGICAL FLUID

In this study, three different Magneto-Rheological fluids designated as YV1M1, YV2M2 and YV3M3 are prepared with 20%, 25% and 30% of volume fraction of iron particles. The ingredients required for the preparation of 200 ml of Magneto-Rheological fluid are as given in Table. The AP 3 grade Grease is first mixed in paraffin oil using mechanical stirred for about 20 minutes till the grease is dissolved in the oil completely. Then the oil is allowed to settle for about three hours. The iron particles are then added in the mixture of Grease and oil. This mixture is stirred for 15 to 20minutes, until all particles get mixed in the oil completely.

Table 1: The details of ingredients

Details of ingredients	YV1M1(20 %iron particles)	YV2M2(25 %iron particles)	YV3M3 (30 %iron particles)
Low viscosity oil (Paraffin oil)	160 ml	150 ml	140 ml
Iron Particles(around50 micron)	140.4 gm	175.5 gm	210.6 gm
AP 3 grease(12% of Oil weight)	16 gm	15 gm	14 m

III CALCULATION TO PREPARE MAGNETO-RHEOLOGICAL FLUID

The calculations of ingredients which are required to prepare 200ml of three different types of Magneto-Rheological fluids (YV1M1, YV2M2 and YV3M3) are as given below.

For YV1M1: (80% paraffin oil + 20% iron particles)

1. 200ml of fluid X 80/100 of paraffin oil = 160ml of paraffin oil
   160ml X specific gravity of low viscosity paraffin oil 0.8282 = 132.51gm
2. 132.51gm of paraffin oil X 12/100 = 16gm of AP3 grease
3. 200ml of fluid X 20/100 of iron particles = 40 ml of iron particles
   40 X 3.51 = 140.4gmof iron particles

For YV2M2: (75% paraffin oil + 25% iron particles)

1. 200ml of fluid X 75/100 of paraffin oil = 150ml of paraffin oil
   150ml X specific gravity of low viscosity paraffin oil 0.8282 = 124.23gm
2. 124.23gm of paraffin oil X 12/100 = 15gm of AP3 grease
3. 200ml of fluid X 25/100 of iron particles = 50 ml of iron particles
   50 X 3.51 = 175.5gmof iron particles

For YV3M3: (70% paraffin oil + 30% iron particles)

1. 200ml of fluid X 70/100 of paraffin oil = 140ml of paraffin oil
   140ml X specific gravity of low viscosity paraffin oil 0.8282 = 115.95gm
2. 115.95gm of paraffin oil X 12/100 = 14gm of AP3 grease
3. 200ml of fluid X 30/100 of iron particles = 60 ml of iron particles
   60 X 3.51 = 210.6gmof iron particles

IV MAGNETO-RHEOLOGICAL FLUID CHARACTERISTICS TESTING

The magnetic induction (H) and the flux density (B) of the above mentioned three types of Magneto-Rheological fluids are determined experimentally. The experimental set for the same, consists of an electromagnet, digital Gauss meter and sensor rod arrangement as shown in figure1. The sensor probe was dipped in the cup having 30 ml Magneto-Rheological fluid and this arrangement was kept in the electromagnetic field generated by the coil.

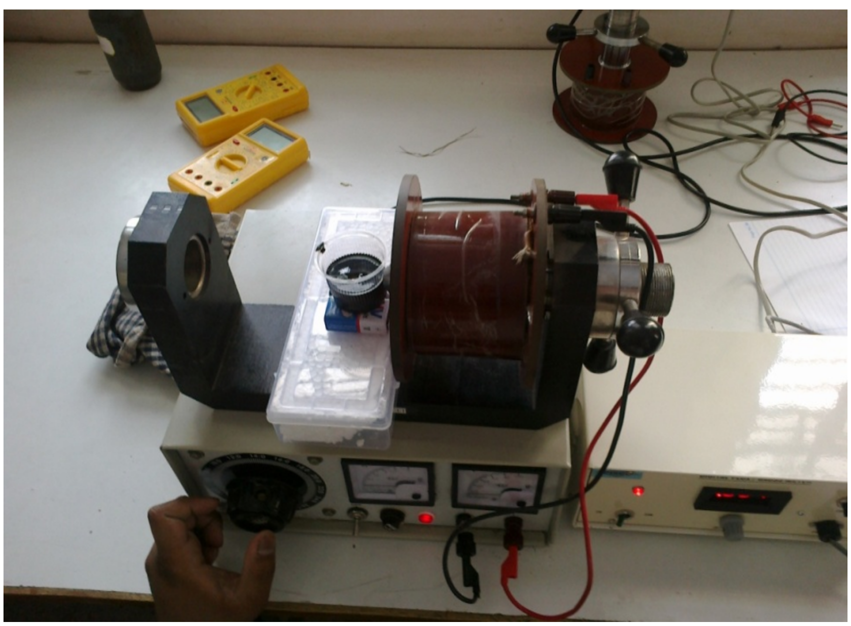

Figure 1: Experimental set up for Magneto-Rheological Fluid characterization

This experimental arrangement can be explained with the help of block diagram, as shown in Figure 2. The current (I) of the coil is varied as 0.3, 0.6, 0.9, 1.2, 1.5, 1.8 and 2.1 Amperes. To vary magnetic induction (H) and flux density (B) is measured using sensor and digital gauss meter. The magnitude of magnetic induction and flux density for Magneto-Rheological fluids YV1M2, YV2M2 and YV3M3 are given in Tables 2, 3 and 4 respectively.

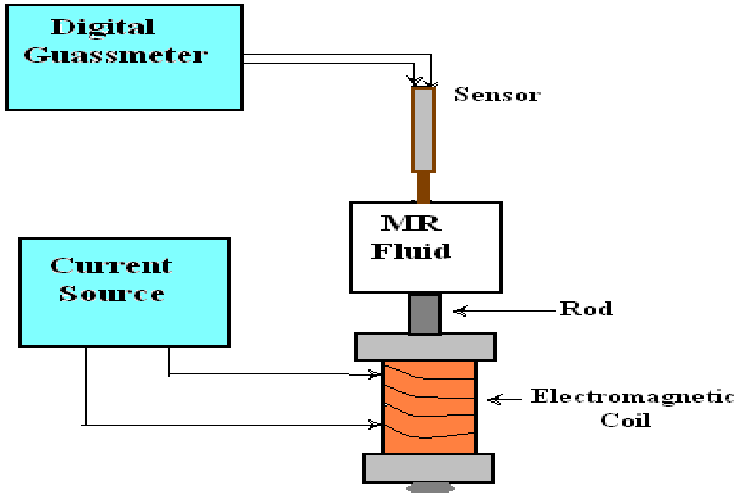

Figure 2: Experimental set up for Characterization of Magneto-Rheological damper

Table 2 Characteristics for YV1M1 (20% iron particles)

Sr. No	Current in Amp	Magnetic Flux Density (Tesla) 'B'	Magnetic induction (Amp/m) H
1.	0.3	109	9432
2.	0.6	210	18864
3.	0.9	343	28296
4.	1.2	464	37728
5.	1.5	560	47160
6.	1.8	624	56292
7.	2.1	654	66024

Table 3 Characteristics for YV2M2 (25% iron particles)

Sr. No	Current in Amp	Magnetic Flux Density (Tesla) 'B'	Magnetic induction (Amp/m)H
1.	0.3	130	9432
2.	0.6	258	18864
3.	0.9	400	28296
4.	1.2	554	37728
5.	1.5	681	47160
6.	1.8	785	56292
7.	2.1	856	66024

Table 4 Characteristics for YV3M3 (30% iron particle)

Sr. No	Current in Amp	Magnetic Flux Density (Tesla) 'B'	Magnetic induction (Amp/m) H
1.	0.3	199	9432
2.	0.6	392	18864
3.	0.9	562	28296
4.	1.2	723	37728
5.	1.5	910	47160
6.	1.8	1065	56292
7.	2.1	1177	66024

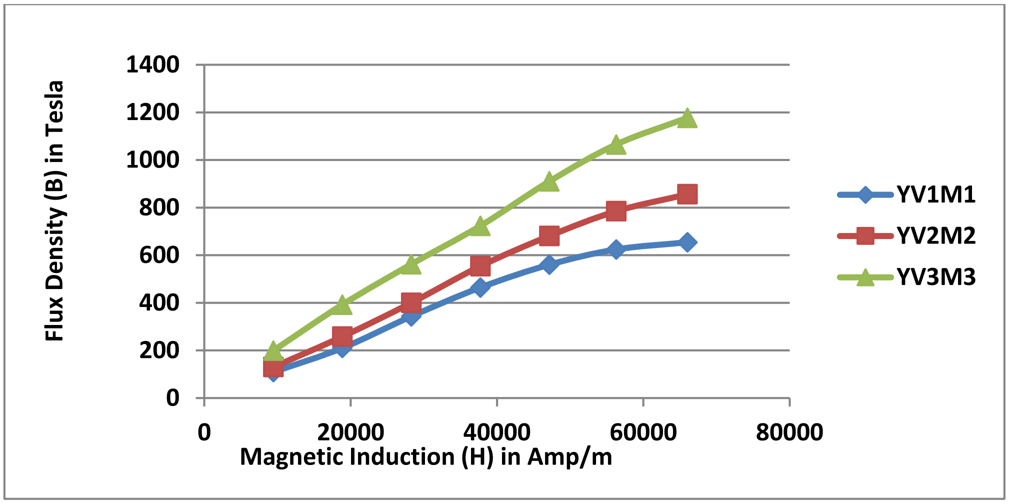

Figure 3: B-H curve for YV1M1, YV2M2 and YV3M3

The B-H curves for three types of Magneto-Rheological fluids are given in Figure 3. It is observed that in the initial phase, the magnetic induction B-H relation is almost linear. As the value of magnetic induction increases, the B-H curve becomes non linear. It can also be observed that the magnetic induction values increases with increase in volume percentage of iron particles. Thus, it is clear that the Magneto-Rheological fluids developed in this study can be used in the further experimentation for damper testing.

Figure 4: Experimental setup for modified classical MR damper testing

The force amplitude and displacement amplitude are measured at specific frequencies of 2, 4 and 6 Hz and damper currents (I_d) of 0.01, 0.5, 1,and 1.5 Amp by varying excitation current (I_e) as 1.5, 3, 4.5 and 6 Amp. The experimental results obtained are given in Table 5, 6. and 7. The Force-Displacement characteristics curves are then plotted for all three types of Magneto-Rheological fluids at different current inputs for different excitation frequencies.

Table 5 shows Force-Displacement characteristics obtained for the modified classical damper set with YV1M1 fluid (20% iron particles volume fraction) at different excitation frequencies. From this table it is observed that with increase in displacement, force also increases. Also, with increase in excitation frequency the value of force decreases for the some value of displacement. The difference between on-state force and off-state force for this damper is set about 0.1 to 0.4 N. It is also observed that the force variation due to change in current is small.

Table 5 : Force- Displacement for 1 dof set with YV1M1 fluid

Sr. No.	Ie(A)	Magnetic Flux	2Hz		4Hz		6Hz	
			d (mm)	F (N)	d (mm)	F (N)	d (mm)	F (N)
1	1.5	0	0.02	0.4	0.04	1	0.05	1.7
2	3	0	0.07	1.8	0.13	2.5	0.12	2.5
3	4.5	0	0.21	3.4	0.26	3.8	0.28	3.6
4	6	0	0.4	5.2	0.44	5.4	0.46	4.3
5	1.5	2000	0.01	1.2	0.03	1.1	0.03	1
6	3	2000	0.06	2.3	0.12	2.4	0.17	1.9
7	4.5	2000	0.23	3.7	0.18	3.4	0.35	3.6
8	6	2000	0.41	5.4	0.4	5.2	0.49	4
9	1.5	4000	0.01	1.4	0.03	1.2	0.04	1.1
10	3	4000	0.06	2.2	0.14	2.2	0.19	1.7
11	4.5	4000	0.22	3.6	0.32	3.2	0.4	3.5
12	6	4000	0.4	5.4	0.43	5	0.54	4.2
13	1.5	7000	0.01	1.3	0.03	1.3	0.04	1.2
14	3	7000	0.06	2.9	0.13	2.4	0.18	1.6
15	4.5	7000	0.23	3.9	0.25	3.5	0.43	3.6
16	6	7000	0.39	5	0.43	5.1	0.6	4.2

Table 6: force-displacement reading for 1dof set with YV2M2 fluid

Sr. No.	Ie(A)	Magnetic Flux	2Hz		4Hz		6Hz	
			d (mm)	F (N)	d (mm)	F (N)	d (mm)	F (N)
1	1.5	0	0.01	1	-	-	-	-
2	3	0	0.05	1.5	0.08	1.8	0.07	1.3
3	4.5	0	0.17	3.3	0.13	3	0.16	1.9
4	6	0	0.29	4.6	0.26	3.9	0.24	2.5
5	1.5	2000	-	-	-	-	-	-
6	3	2000	0.07	2.4	0.05	1.4	0.06	1
7	4.5	2000	0.14	3.2	0.14	2.6	0.15	1.7
8	6	2000	0.24	4.6	0.24	3.6	0.24	2.3
9	1.5	4000	-	-	-	-	-	-
10	3	4000	0.05	1.5	0.08	1.3	0.06	0.9
11	4.5	4000	0.13	3	0.15	2.7	0.14	1.5
12	6	4000	0.27	4.2	0.27	4	0.26	2.3
13	1.5	7000	-	-	-	-	-	-
14	3	7000	0.06	2.3	0.05	2.3	0.07	2.1
15	4.5	7000	0.12	3.4	0.14	3.1	0.16	2.9
16	6	7000	0.26	4.8	0.28	4.4	0.29	3.6

Table 6 shows the Force-Displacement characteristics for modified classical damper with YV2M2 fluid (25% iron particles volume fraction). It is observed that for the same excitation current, the displacement and the force decreases due to increase in percentage of iron particles volume fraction in the fluid. In this case for 4 and 6 Hz frequencies, the force varies considerably with change in input current. Table7 shows the Force-Displacement characteristics for the modified classical damper with YV3M3 fluid (30% iron particles volume fraction). This indicates that for this fluid the magnetic saturation occurs at this excitation frequency.

Table 7: force-displacement reading for 1dof set with YV3M3 Fluid

Sr. No.	Ie(A)	Magnetic Flux	2Hz		4Hz		6Hz	
			d (mm)	F (N)	d (mm)	F (N)	d (mm)	F (N)
1	1.5	0	-	-	-	-	-	-
2	3	0	0.2	2.7	0.16	2.3	0.21	1.4
3	4.5	0	0.4	3.8	0.4	3.2	0.43	2.3
4	6	0	0.65	4.4	0.76	4.1	0.84	3
5	1.5	2000	-	-	-	-	-	-
6	3	2000	0.08	2.1	0.11	2.1	0.15	1.5
7	4.5	2000	0.28	3.3	0.33	3.5	0.34	2.4
8	6	2000	0.58	4.7	0.53	4.1	0.59	3.1
9	1.5	4000	-	-	-	-	-	-
10	3	4000	0.07	2.1	0.08	2.5	0.11	1.5
11	4.5	4000	0.25	3.3	0.23	3.7	0.29	2.3
12	6	4000	0.47	4.5	0.47	4.9	0.6	3.5
13	1.5	7000	-	-	-	-	-	-
14	3	7000	0.08	3.2	0.12	3.2	0.09	2.8
15	4.5	7000	0.22	4.5	0.26	4.3	0.25	3.7
16	6	7000	0.43	5.7	0.51	5.4	0.61	4.1

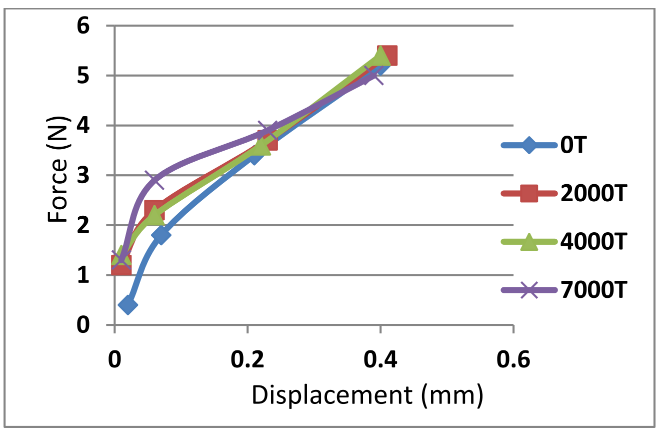

Figure 5: For YV1M1 fluid with 2 Hz

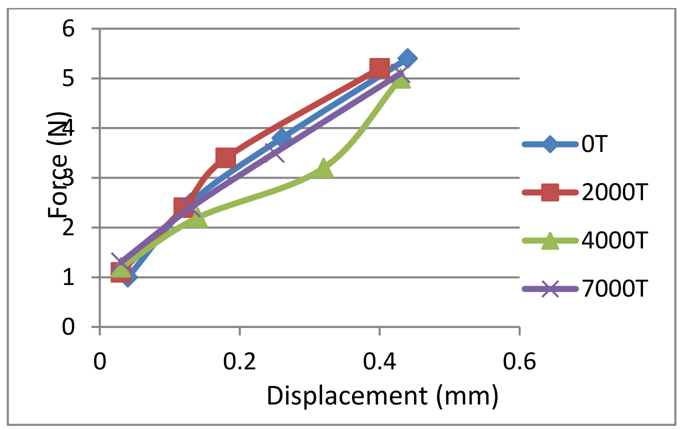

Figure 6: For YV1M1 fluid with 4 Hz

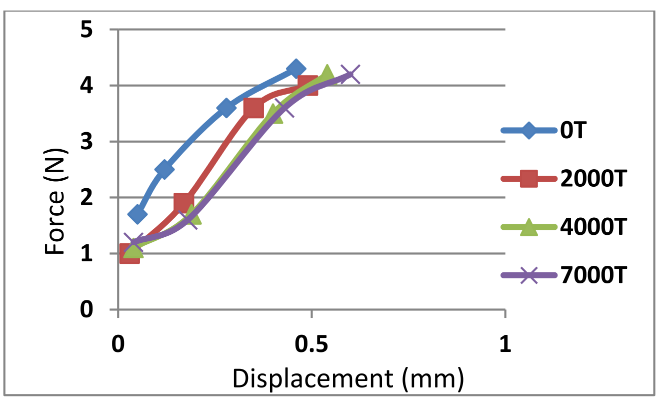

Figure 7: for YV1M1 fluid with 6 Hz

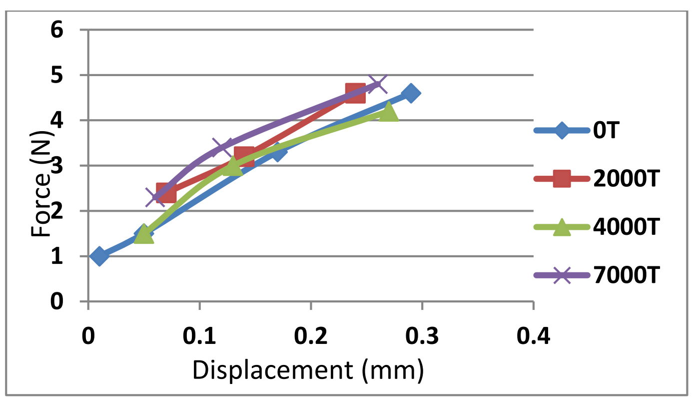

Figure 8: For YV2M2 fluid with 2 Hz

Figure 5, 6 and 7 show Force-Displacement characteristics obtained for the modified classical damper with YV1M1 fluid (20% iron particles volume fraction) at different excitation frequencies like 2, 4 and 6 Hz respectively. From these Figures it is observed that with increase in displacement force increases. However, its nature is not linear. It is also observed that with increase in excitation frequency the value of force decreases for the some value of displacement. The difference between on-state force and off-state force for this damper set is about 0.01 to 0.4 N. It is also observed that the force variation due to change in current is small. .

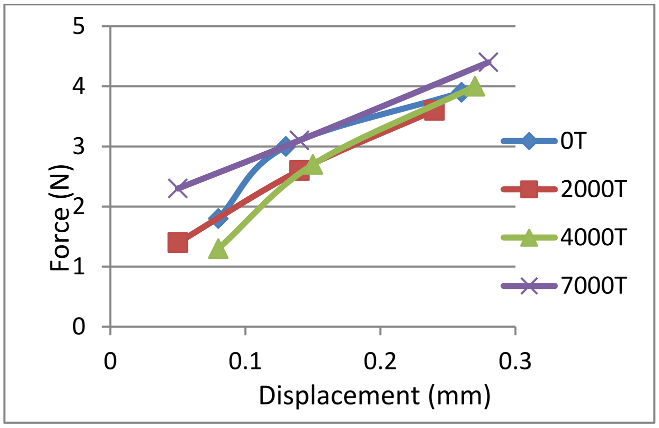

Figure 9: For YV2M2 fluid with 4 Hz

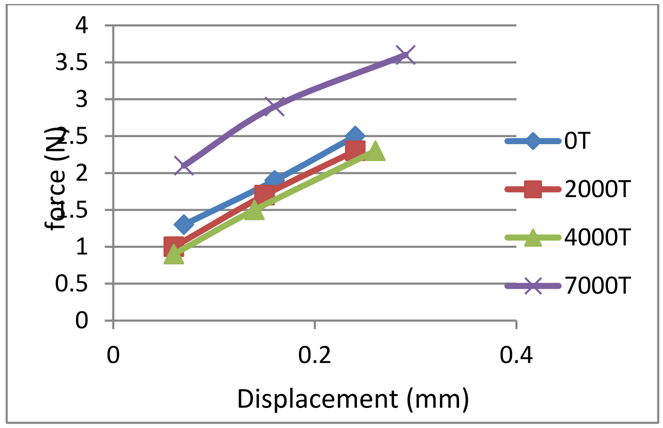

Figure 10: For YV2M2 fluid with 6 Hz

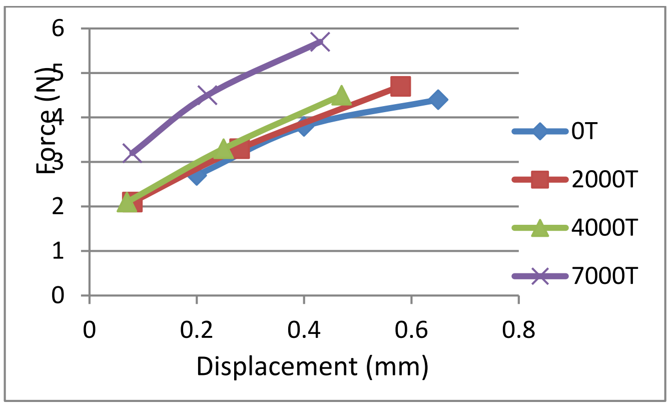

Figure 11: For YV2M3 fluid with 2 Hz

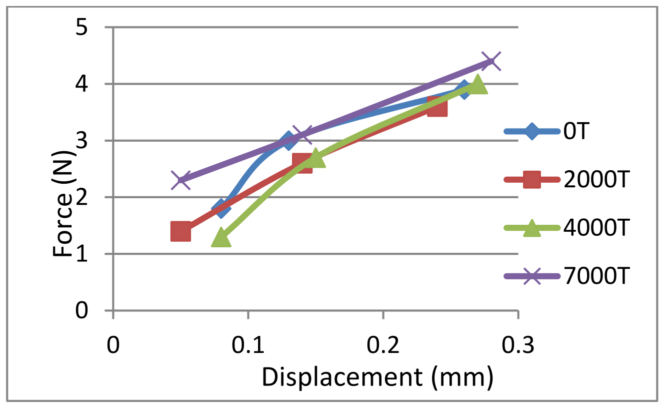

Figure12: For YV2M3 fluid with 4 Hz

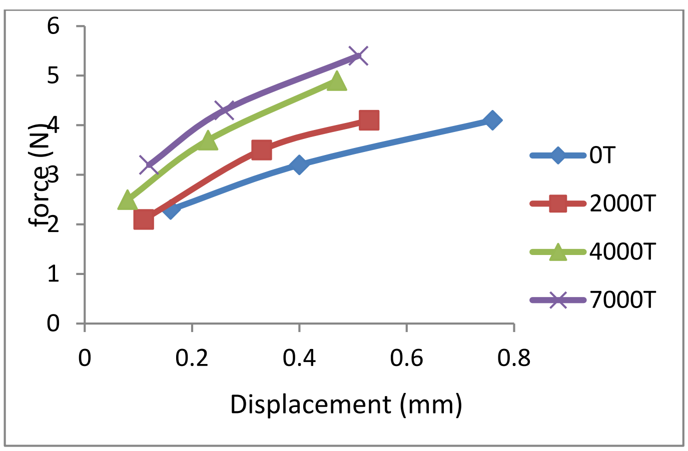

Figure 13: For YV2M3 fluid with 6 Hz

Figure 8, 9 and 10 show the Force-Displacement characteristics for modified classical damper set with YV2M2 (25% iron particles volume fraction) fluid at different excitation frequencies like 2, 4 and 6 Hz respectively. From the figures, it is observed that for the same excitation current displacement and force decreases due to increase in percentage of iron particles volume fraction in the fluid. There is considerable difference in displacement and force readings as compared to YV1M1 fluid and damper result in off state and on state condition In this case for 4 and 6 Hz frequencies the force varies considerably with change in input current.

Figure 11, 12 and 13 show the Force-Displacement characteristics for the modified classical damper with YV3M3 (30% iron particles volume fraction) fluid at different excitation frequencies like 2, 4 and 6 Hz respectively. It is observed that increase in iron particles volume fraction damper performance also improve. However the damper set with Magneto-Rheological fluid YV3M3 suffer from the workability and in turn efficiency. This indicates that for this fluid the magnetic saturation occurs at this excitation frequency.

V. CONCLUSION

Magneto-rheological characteristic of Magneto-rheological fluids is affected by the percentage of iron particles volume fraction in it. Hence, three different fluids with iron particles volume fraction of 20%, 25 % and 30 % were prepared in this study. From the B-H curves of these fluids, it is observed that, as the percentage of iron particles volume fraction increases in the Magneto-rheological fluid, the magnetic flux density value also increases for the same value of magnetic induction. the trend of Magneto-rheological fluid characteristics are very much similar to the results from the litreture.

From this study, it is observed that with increase in iron particles volume fraction and higher excitation current, damper performance improves. However, the damper set with thickest fluid suffers from the problem of workability at lowest damping current. Among the 1 Degree of freedom set used in this study, the set with fluid YV2M2 with 25 % iron particles volume fraction gives better performance workability point of view.

To study the effect of Magneto-Rheological fluids and external permanent magnet arrangement in one degree of freedom set on force-displacement characteristics these combinations of damper set with three fluids are tested from this study it is observed that increase in iron particles volume fraction damper performance also improve. However the 1 dof set with Magneto-Rheological fluid YV3M3 suffer from the workability and in turn efficiency among the damper set used in this study set with gap and turn efficiency.

Among the 1 dof set used this study the damper of fluid with 25% iron particles volume fraction at 6Hz gives better performance from efficiency and workability point of view.

REFERENCES

1) Haiping Dua, Kam Yim Szeb, James Lamb, “Semi-active H control of vehicle suspension with magneto-rheological dampers”, Journal of Sound and Vibration 283 (2005),pp. 981–996.

2) Weng W. Chooi, S. Olutunde Oyadiji, “Design, modeling and testing of Magnetorheological dampers using analytical flow solutions”, journal of Computers and Structures 86 (2008) 473–482.

3) Sevki Cesmeci, TahsinEngin, “Modeling and testing of a field controllable Magnetorheological fluid damper “International Journal of Mechanical Sciences 52 (2010) 1036–1046.

4) Ashfak, A. Saheed, K. K. Abdul Rasheed, and J. Abdul Jaleel, “Design, Fabrication and Evaluation of MR Damper” International Journal of Aerospace and Mechanical Engineering 5:1 2011.

5) R. Turczyn a, M. Kciuk b, “Preparation and study of model Magnetorheological fluids” Journal of Achievements in Materials and Manufacturing Engineering 2008.

6) S. Elizabeth Premalatha, R. Chokkalingam, and M. Mahendran, “Magneto Mechanical Properties of Iron Based MR Fluids“American Journal of Polymer Science 2012, 2(4): 50-55.

7)A. Ghiotti , P. Regazzo , S. Bruschi, P.F. Bariani, “Reduction of vibrations in blanking by MR dampers”CIRP Annals - Manufacturing Technology 59 (2010) 275–278.

8) B. P. Ronge, S. R. Kajale, P. M. Pawar, “Therotical and Experimental analysis of MR fluid dampers: Design and Performance analysis”, LAP launcher academic publication, ISBN 978-3-8454-7757-2, German, Paperback, 192 pages

AUTHORS

First Author – Prof. L. B. Raut , ME (Design), SVERI’s, College of Engineering, Pandharpur, lbraut@coe.sveri.ac.in
Second Author –Prof. Y.M. Khedkar , ME (Design), SVERI’s, College of Engineering, Pandharpur,ymkhedkar@coe.sveri.ac.in
Third Author – Prof. S.Y. Salunke, ME (Design), SVERI’s, College of Engineering, Pandharpur, sysalunke@coe.sveri.ac.in
Fourth Author- Prof. S.V. Jadhav M.Tech.(Energy Engg.) SVERI’s, College of Engineering, Pandharpur, svjadhav@coe.sveri.ac.in