Paper ID: AM-12

Performance Test of an Indigenous Magnetorheological (MR) Damper

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Abstract

Vehicle suspension is generally used to reduce unwanted vibration from various road condition. Automobile suspension systems mostly influence the vehicle ride quality, safety and steering ability. Magnetorheological fluid (MRF) is a fascinating material which has unique rheological property. One of the most popular MRFs device is the MR damper. Comparing to conventional damper, MR damper has the capability of changing the viscosity of the fluid with the change in magnetic field intensity. MR damper has the advantage of high strength, fast response rate and simple structure. In this work, MR fluid is prepared in a certain composition and design of MR damper piston is modified so that the current effects the magnetization to carry the load of a vehicle. The compression test of MR damper is done through Universal Testing Machine.

1.Introduction

Shock absorber / Damper is a mechanical device designed to smooth out any sudden shock and to dissipate kinetic energy which is mostly used in automobiles [1]. The purposes of damper are to control the movement of springs and suspension and to keep tires in contact with ground at all times [2].

2.MR Damper

This type of damper works in the presence of MR fluid or smart fluid in automobiles as chassis shock absorber, seat and cab suspensions, automobile brake system, railway vehicles etc. In Figure 1(b), coil and fluid flowing gap is shown.

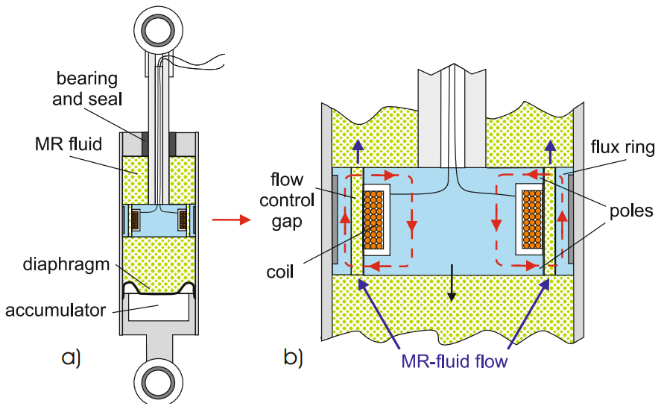

Figure 1. MR Shock Absorber

3.MR Fluid

Magnetorheological (MR) fluids are materials that respond to an applied magnetic field with a change in rheological behavior. They are basically a suspension of magnetic particles in a liquid. Under influence of magnetic field, the suspended magnetic particles interact to form a structure that resists shear deformation or flow. This is because of the polarization of the suspended particles. This change in the material appears as a rapid increase in apparent viscosity or in the development of a semisolid state [5]. The interaction between the resulting induced dipoles causes the particles to form columnar structures, parallel to the applied field. Figure 2 represents the chain like structure of MR fluid during power off, power on (minimum) and power on (maximum).

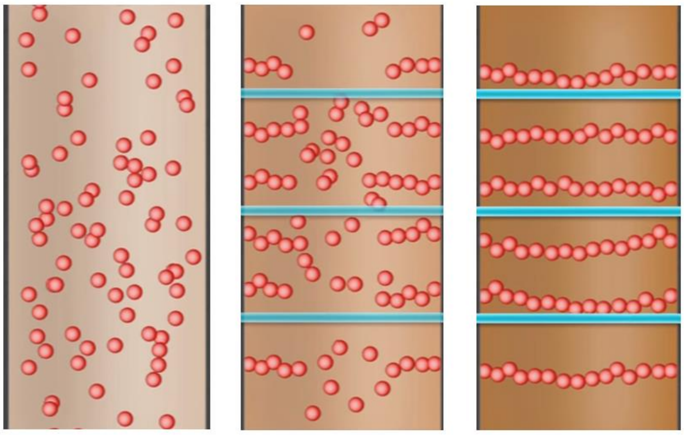

Figure 2. Power off, Power on minimum, Power on maximum

These chain-like structures restrict the motion of the fluid, thereby increasing its viscosity. The mechanical energy needed to yield these chain-like structures increases as the applied field increases resulting in a field-dependent yield stress. In the absence of the magnetic field, the liquid behaves like a Newtonian fluid. Thus, we can control the fluid on the basis of the magnetic field supplied [6]. The discovery of MR fluids is credited to Jacob Rabinow in 19494 Advances in the application of MR materials are parallel to the development of new and more sophisticated MR materials with better properties and stability.

4.MR Fluid Composition (Percentage by Volume)

MR fluid (250 mL) consists of soybean oil (122.5 mL), Carbonyl Iron Powder (112.5 mL CIP) and solution of grease and oleic acid (2.5 mL). Mixing of ingredients is shown in table 1 [9].

Table 1. Solution and Ingredients

Solution	Ingredients		
250 mL MRF Solution	122.5 mL Soybean Oil (49% by total volume)	112.5 mL CIP (45% by total volume)	2.5 mL (Grease + Oleic Acid Solution) (1% by total volume)

5.Ingredients:

At first, grease, oleic acid, soybean oil and CI powder was collected. CI powder was ordered from Germany through a German chemical company named BASF. The CI powder container was collected from SAM Tower, Gulshan, Bangladesh. In Figure 4, the components for the preparation of MR fluid was shown.

Figure 4. Oleic Acid, Grease and Soybean Oil (Left), CI Powder Container and CI Powder (Right)

For the preparation of MR fluid, solution of grease and oleic acid was prepared at first by using coffee maker for 10 minutes which is shown in Figure 5(a). Only 2.5 mL was taken from the solution for the preparation of MR fluid. After that, soybean oil of 122.5 mL was mixed with the 2.5 mL solution of grease and oleic acid which is shown in Figure 5(b) using the coffee maker for around 15 minutes.

(a) (b) (c)

Figure 5. Mixture of (a) Oleic Acid and Grease, (b) Oleic Acid, Grease and Soybean Oil, (c) Oleic Acid, Grease, Soybean Oil and CI Powder

CI powder of 112.5 mL was mixed with the solution using spoon for around 25 minutes which is shown in Figure 5(c). In the last mixture, coffee maker was not used as the viscosity of the MR fluid was high than the other solution. The prepared MR fluid was covered by a paper for further use at the time of assembly of the MR damper.

6.Modeling of Conventional MR damper

A MR damper piston is designed modifying the fluid flowing section from passages to 6 holes of 2 mm diameter which is shown in Figure 7(c). The height of the damper piston is 11.95 mm which was used for winding of copper wires. The modified design is given below in Figure 7(a), (b) & (c):

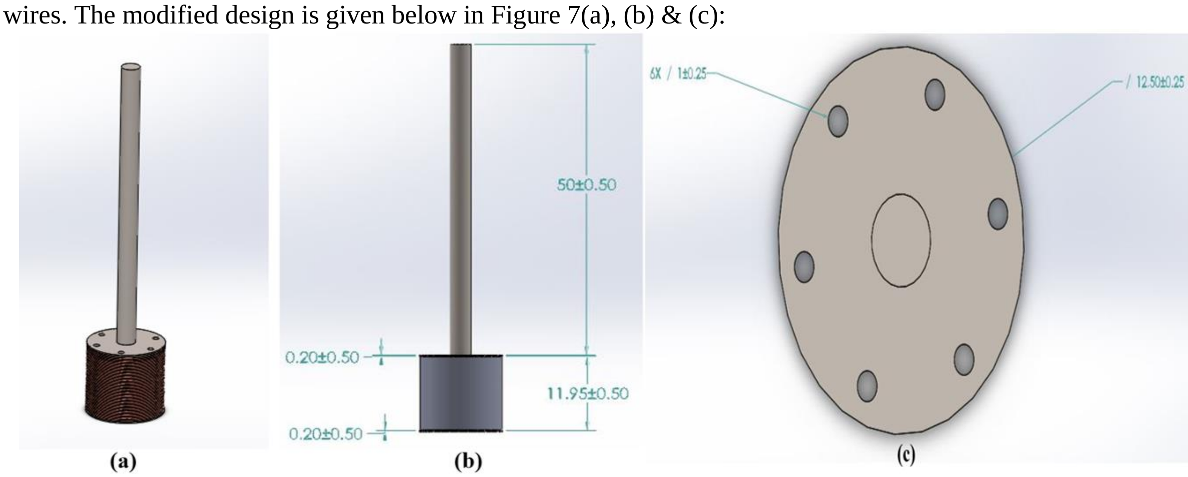

Figure 7. Proposed Design of MR Damper Piston (a) 3D View (b) Front View, (c) Top view

7.Implementation:

At first, a conventional chassis shock absorber was taken which is shown in figure 8. It was machined in lathe machine to uncover the piston and piston assembly shown in figure 8.

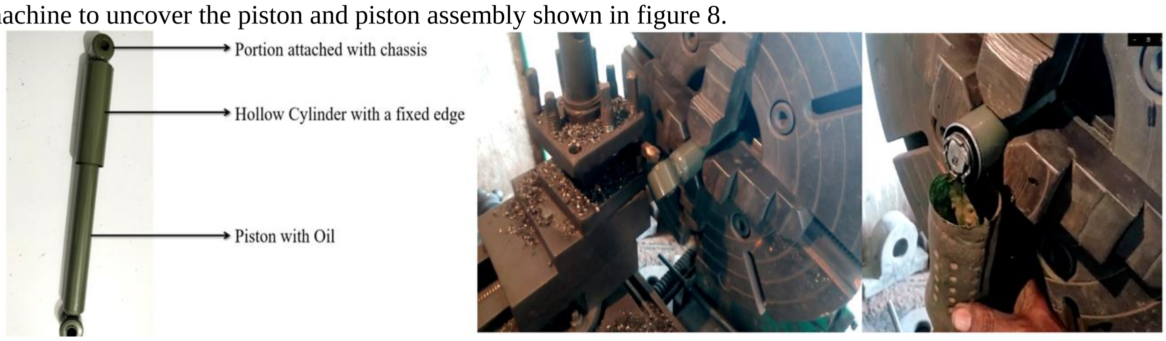

Figure 8. A Chassis Shock Absorber (Left), Machining of Shock Absorber and Collection of fluid (Left)

At the end of the machining process, the fluid was collected to measure the actual amount of fluid contained inside the piston housing. The piston assembly is dismissed and the piston was observed. It consisted of 6 holes of 2 mm in diameter. After that, the outer surface of the piston was machined in lathe machine to decrease the diameter of the piston so that the outer surface would be open to the 6 holes. Then, a copper wire of 26 gauge was winded over the outer surface of the piston. It was about 55 turns. After that, turned wire was covered using a tap and the two point of the wires was opened to the outer side of the casing shown in figure 9.

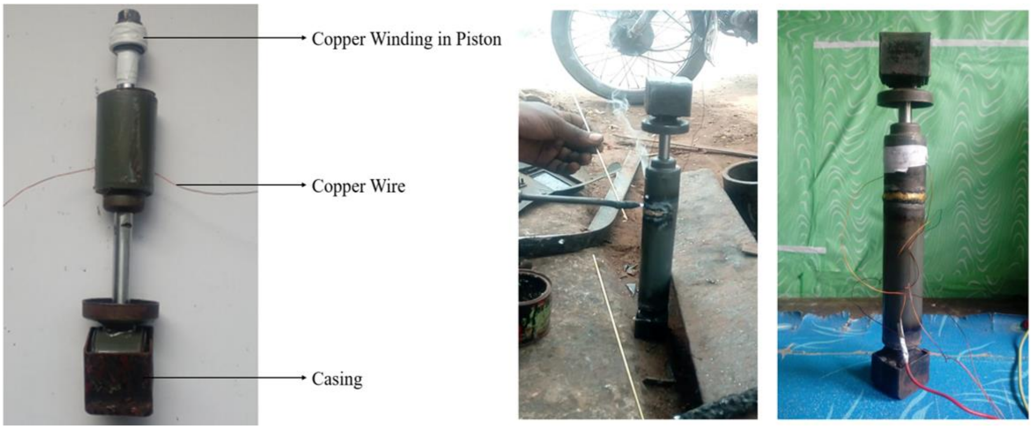

Figure 9. Copper winding in piston and attached casing (Left), Gas Wielding of MR damper (Middle), Final Finished MR damper (Right)

8.Final Finishing of MR Damper:

After filling MR fluid in the housing of MR damper, it was joined by gas wielding for better sealing. As during compression, a high pressure was developed in the MR damper. So, it was joined by gas wielding which is shown in figure 9.

9.Testing:

A DC power supply was used to vary the current to control its viscosity. With the increase of current, the magnetization increases in the coil and so the viscosity of the fluid also increases. After that, the MR damper was set to the UTM to measure the force carried by the damper to absorb the shock shown in figure 10.
Force was applied by the UTM at different times to take the readings.

(a) **(b)** **(c)**

Figure 10. (a) DC Power Supply, (b) UTM, (c) MR Damper attached to UTM

10.RESULTS

Simulation Results

Simulation of magnetization effect in MR damper was done in ANSYS APDL software. APDL stands for ANSYS Parametric Design Language.

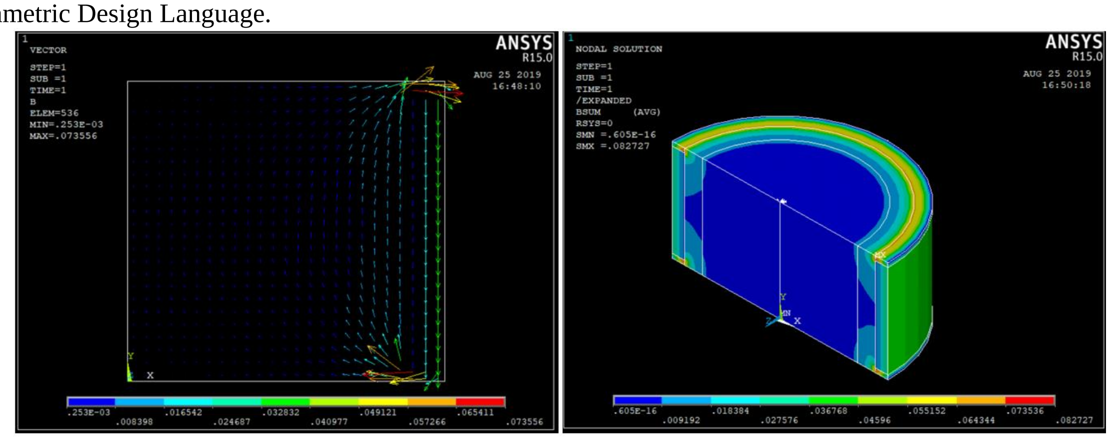

Figure 11. Magnetic flux gradient (Left), Summation of magnetic flux for half part of piston (Right)

Figure 11 (Right) shows the magnetic flux gradient which is highest in the red zone and lowest in the blue zone. It is showing the magnetic field in Tesla. Magnetic flux is very high at the copper wire and it's reducing to the center of the piston. Figure 11 (Right) shows the summation of magnetic flux gradient for half part of the piston. And all the data are as same as one-fourth part of the piston. The simulation was axisymmetric. So, it was easy to compute the data for one-fourth part of the piston.

Compression Test Results

These values were taken from the compression test of MR damper using Universal Testing Machine.

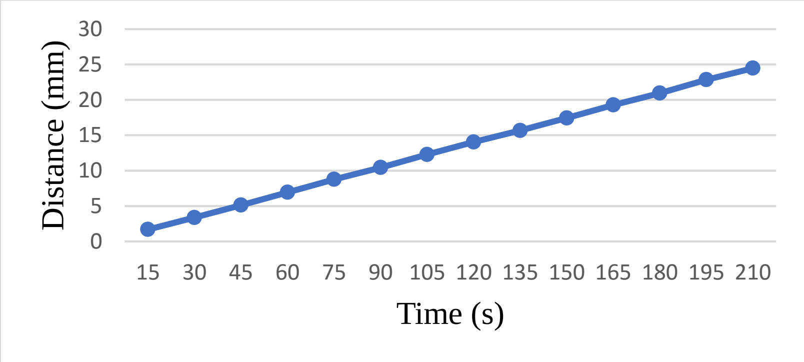

Figure 13. Distance vs Time curve for 3A current

Figure 13 shows that at 15 seconds, damper travels 1.69 mm and it gradually increases and after 3 minutes and 30 seconds, damper travels 24.47 mm which is maximum.

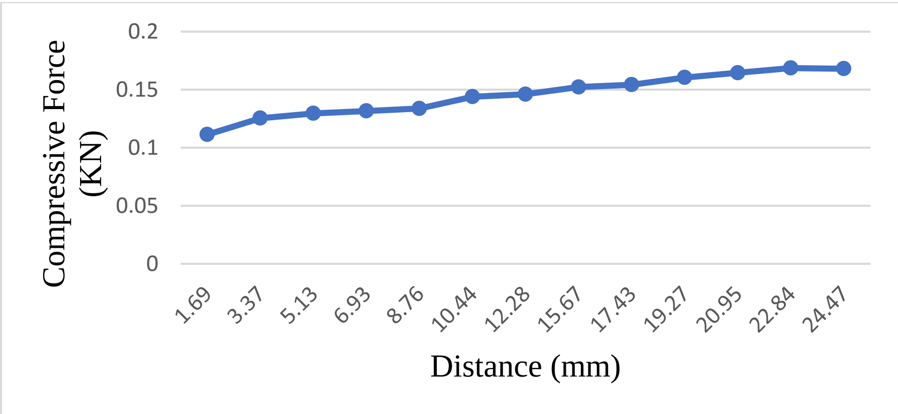

Figure 14. Compressive Force vs Distance curve for 3A current

Figure 14 shows that at 1.69 mm, compressive force is 0.1113 KN and it gradually increases and at 24.47 mm, compressive force is 0.168 KN which is maximum and represents 17.12 kg.

11.Conclusion

In this work, MR fluid and an indigenous MR damper was prepared. Performance of MR damper was tested through Universal Testing Machine (UTM) in Metrology lab. The MR damper can carry maximum 17.19 kg load for 3A current supply.

12. References

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