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Finite Element Analysis of Magneto-rheological Damper

Deepika Pujari[1], Rahul N. Yerrawar[2]
[1, 2] Department of Mechanical Engineering, Savitribai Phule Pune University

Abstract*: Magneto-rheological (MR) dampers being a semi-active control tool has received a lot of attention in recent years due to its structural simplicity, wide range of applications, low energy consumption, high capacity and high reliability. MR dampers are being developed for a variety of applications where controllable damping is desired. MR fluids represent a class of smart materials, whose rheological properties change in response to the application of a magnetic field. MR fluid dampers are also a new type of vibration control elements. They have the advantages of rapid damping and stiffness changing in the presence of an applied magnetic field. Automobile suspension and structural vibration control systems are among the most frequent uses of such type of dampers.

Keywords*: Magneto rheological fluids, MR fluids, magneto rheological fluid dampers, MR damper design.

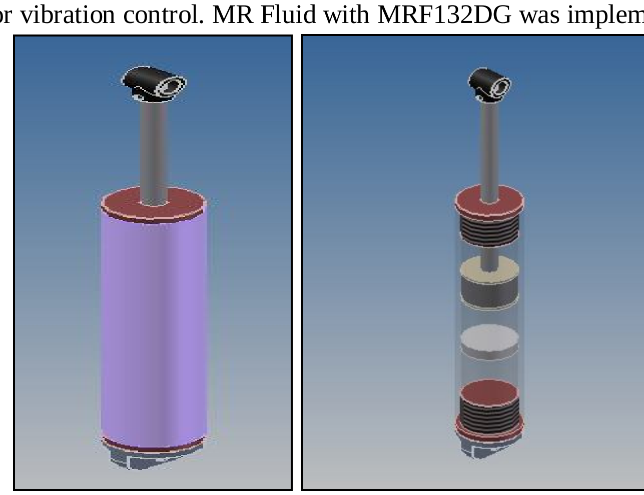
I. INTRODUCTION

A shock absorber has significant impact on performance of suspension system. Passive, active, and semi-active are three types of suspension system which have been implemented. MR Damper is a semi-active vibration controlling device. It can have real-time adjusting systems to change damping based on certain physical measurements, such as velocity or acceleration, in order to counteract and control the system dynamics. The objective is to provide a design analysis of some of the parameters in MR dampers that can have a significant effect on the force-velocity characteristics of MR dampers. It also important to understand effect of different geometric designs on performance of damper and the force-velocity characteristics a MR damper.

II. MR DAMPER MODEL

MR damper as shown in the Fig. 1 consists of two chambers in the cylinder which is separated by a floating piston. Out of the two sections a section of the piston head is filled with MR fluid, and the other is an accumulator. An accumulator filled with pressurized nitrogen gas, compensates the volume changes induced by the sliding of the piston rod from BDC to TDC and vice versa. The fluid flows to the other side of piston head through the annular gap during the motion of piston. A coil is located inside the piston and heat-resistant coil wire is used for winding which is also electrically insulated. An application of electrical current to the coil generates a magnetic field around the piston head in the cylinder.

MR fluid contain oil and iron particles which vary in percentages according to the specifications. The fluid's adjustable viscosity makes it ideal for use in dampers for vibration control. MR Fluid with MRF132DG was implemented.



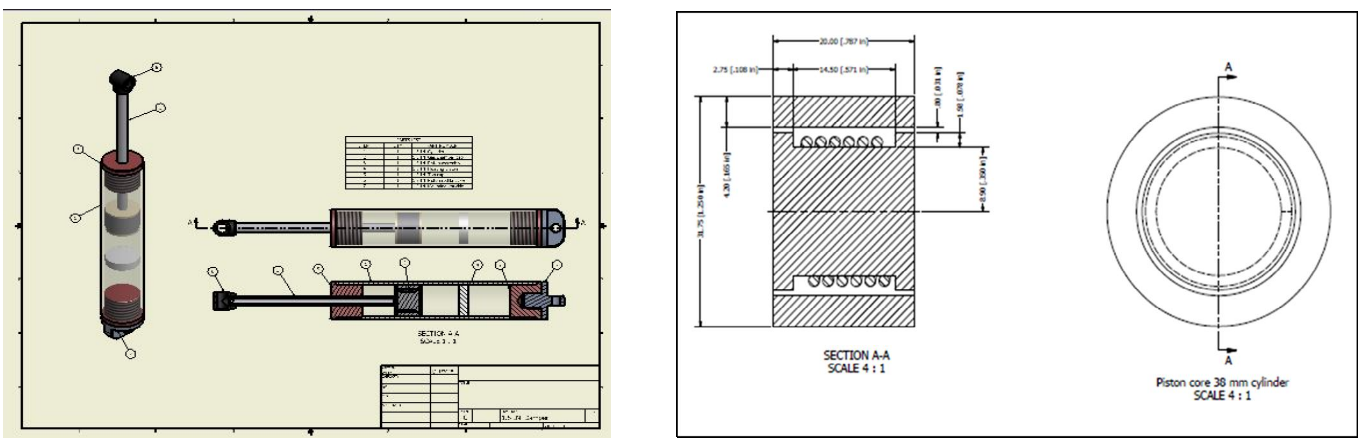
(a) (b)

Fig. 1 Inventor (a) 3D model view (b) 3D model showing all components

Three diameter sizes of cylinder, with outer diameters of 1 ¼, 1 ½, 1 ¾, (Inch) and wall thickness of 1/8 (Inch), were considered as shown in Table I. Analysis was performed for all and the results were accumulated.

TABLE I
Damper variants and dimensions

Components	Material	Description	Dimensions Variant 1	Dimensions Variant 2	Dimensions Variant 3
Cylinder	Aluminum 7075 tube	Outer diameter Wall thickness	1-1/4 [in], 34 [mm] 1/8 [in], 6.35 [mm]	1-1/2 [in], 38 [mm] 1/8 [in], 6.35 [mm]	1-3/4 [in], 42 [mm] 1/8 [in], 6.35 [mm]
Cylinder caps	Aluminum 7075 bar	Diameter	1-1/2 [in], 34 [mm]	1-1/2 [in], 34 [mm]	1-1/2 [in], 34[mm]
Shaft	Aluminum 7075 rod	Diameter	3/8 [in], 9.52 [mm]	3/8 [in], 9.52 [mm]	3/8 [in], 9.52 [mm]



(a) (b)

Fig. 2 Detailed Inventor drawing (a) MR Damper (b) Piston core of 38 mm dia cylinder

III. ANALYSIS OF MR DAMPER

Analysis is typically carried out in three steps

A. Pre-Processing

ANSA is used. In ANSA, Inventor model is imported in the form of neutral format (i.e STEP or IGES). Meshing criteria is decided as per geometry. Material property, load and boundary conditions are applied to meshed model.

B. Processing

ABACUS solver would be used to solve the model.

C. Post-processing

ABACUS output would be used to study the results in the form of graphs or contour.
Analysis Type: Dynamic, Explicit
In the set of experiments, a number of tests were performed on all three dampers over range of frequencies and amplitudes of input displacement. Table shows all simulation scenarios performed on the dampers.

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TABLE III
Amplitude and frequency inputs

Amplitude= 8mm	Amplitude= 13mm	Amplitude= 23mm
2Hz	2Hz	2Hz
4Hz	4Hz	4Hz

IV.RESULTS

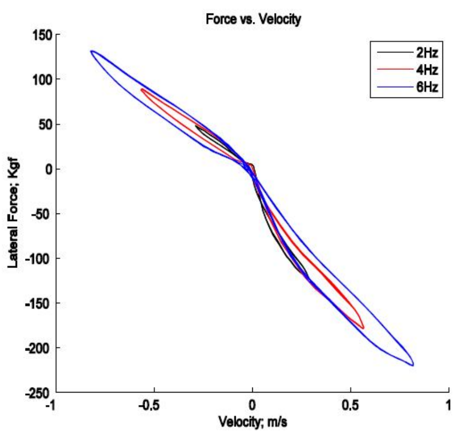
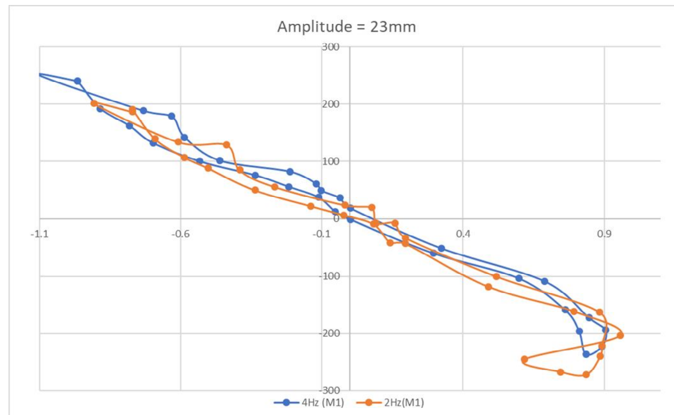
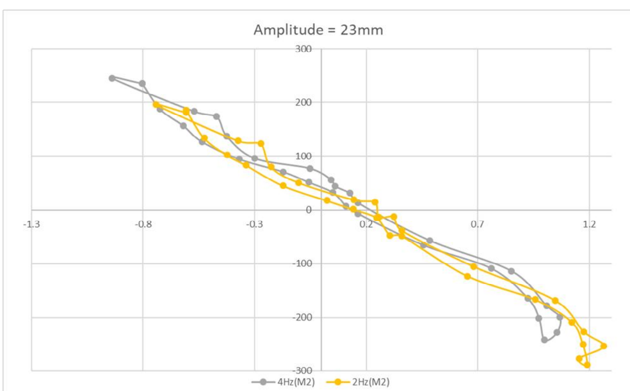


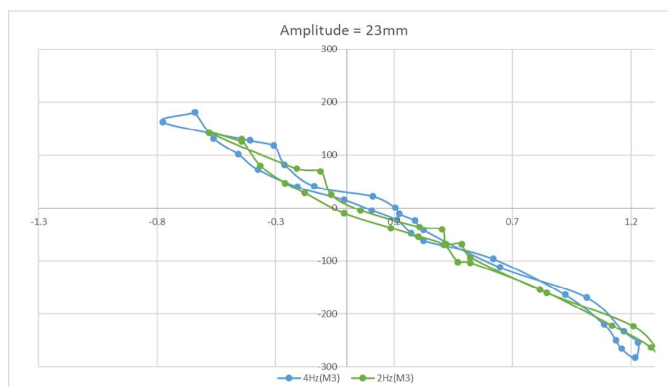
Fig. 3 Experimental graph



(a)



(b)



(c)

Fig. 4 Velocity graphs generated for (a) 34mm cylinder dia. (b) 38mm cylinder dia. (c) 42 mm cylinder dia.

V. CONCLUSIONS

The experiments on force vs. velocity plots start at zero velocity at BDC. It then follows the curve in counter clockwise and clockwise directions, respectively. The actuator compresses the shock from low speed (0.0 m/s) at point BDC and then accelerates until the maximum velocity is reached. The compression decelerates to point TDC where shocks reach zero speed again. The shock rebound can be seen on the plot starting at point TDC which accelerates to the maximum speed at the mid-stroke. From here, the shock rebound circuit is under deceleration until BDC is reached.

Also the characteristic of the damper is almost linear when considering the force vs. velocity curve (a desirable feature in mountain bicycle damper design. Comparing all the models Variant 3 provides more stabilized damping response to the similar to experimental test procedure also limiting the velocity in accordance to the experimental results concluding the optimistic behavior under three simulation data.

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