Modeling And Simulation of MR Damper Using COMSOL

Mr.Y.M.Khedkar1, Prof.Dr.S.B.Joshi2, Prof.Dr.P.M.Pawar3, Prof.Dr.B.P.Ronge4
1.Assistant Professor, Mechanical Engineering Department, SVERI's College of Engineering, Pandharpur, District Solapur, Maharashtra, India
2.Principal,Brahmdevdada Mane Polytechnic,Belati, Solapur, Maharashtra, India
3.Dean, Research and Development, SVERI's College of Engineering, Pandharpur, District Solapur, Maharashtra, India
4.Principal, SVERI's College of Engineering,Pandharpur, District Solapur, Maharashtra, India

Abstract: Classical hydraulic dampers are flexible devices that are used to attach a component to a mounting base. Vibration amplitude reduction can be achieved by improving the old technique of suspension by bringing in application of Magnetorheological or Electrorheological fluid in it. Due to the controllable characteristics of the material used in the classical hydraulic damper, the design and application of such devices has been area of recent interest. Completely new design of dampers for the existing systems is a complicated process. To manufacture a new MR damper, new process needs to be developed which may become cumbersome. Considering this requirement, classical damper was modified into MR damper by using an external arrangement without any changes in the internal design of the classical damper. The required electromagnetic field was generated with the help of external permanent magnets. Such magnets were attached to movable aluminum rods so as to vary the distance and in turn, the magnetic field surrounding the damper. The MR damper was modeled using COMSOL and under varying magnetic and excitations, the results were observed using simulations. These results were validated experimentally by testing the MR damper under varying external fields using a vibration exciter.

Keywords: Modeling, Simulation, COMSOL, Classical Damper, MR Damper, force-velocity curves.

1. Introduction

Vibration reduction may be considered as key component in the performance of Mechanical Engineering and structures for safety and comfort of their occupants. To reduce the system vibration, active vibration control of the isolation is necessary. Vibration control techniques have classically been categorized into two areas, passive and active controls.

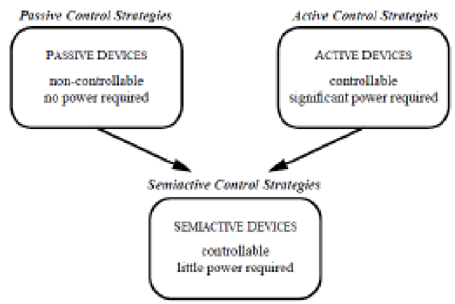

Figure 1: Comparison of vibration reduction approaches [1]

MR dampers are semi-active devices, which are same as passive dampers. MR fluid is used in these dampers. MR fluids are state controllable fluids which can change from liquid to semisolid when magnetic field. MR damper is has benefits such as low manufacturing cost, quick response, change in viscosity in a few milliseconds, ease of construction, low operating power requirements and more effective vibration absorption than passive devices. Such rheological properties of MR fluid depend on size of particles, the carrier fluid properties, additives and stabilizing agents, applied magnetic field, temperature, concentration and density of particles, etc. At the time of designing of the MR fluid devices, it is very important to know the magnetic properties of MR fluid. Magnetic flux density generated in the damper due to electric coil is proportional to the applied filed. MR fluids are environmentally robust and not sensitive to impurities encountered during manufacturing and usage, where performance is greatly affected by the presence of contaminants, especially water or moisture. [1]

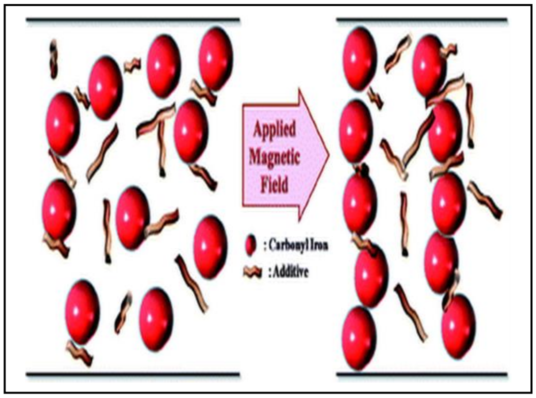

Figure 2: MR fluid ferrous particles behavior in energized and denergized modes

In the following section of paper the general model as well as COMSOL modeling of damper is discussed. In this study concentration is provided at the MR fluid Gap which is designed at piston head. Simulation is carried out by increasing such MR fluid gap. Effect of external magnetic field on viscosity of MR fluid at Piston gap is also part of this simulation.

2. General Design of MR damper

The damper used for simulation is utilized for shock absorbing purpose. To understand the effect of various design parameters such as permanent magnet, types of fluid and excitation frequency on the performance of MR damper, modified classical MR damper of a typical size is fabricated. It is a monotone type, single stage damper consisting of various key components like cylinder with caps, piston having rubber seal, piston rod, diaphragm, external magnet assembly coils etc. The details of these components are given below.

Table 1: The design specifications of modified classical MR damper cylinder

Sr.No.	Parameters	Dimension in mm
1.	Outer diameter of external cylinder	27.5
2.	Inner diameter of external cylinder	26
3.	Height of external cylinder	115
4.	Outer diameter of internal cylinder	18.5
5.	Inner diameter of internal cylinder	17.5
6.	Height of internal cylinder	155
7.	Diameter of Piston	17.5
8.	Gap in piston contains MR fluid	01

In order to study the effect of MR fluid gap when viscosity is steady, the diameter of such gap is varied. As magnetic field energizes ferrous particle present in MR fluid its viscosity increases. The stimulation of MR damper model by varying viscosity is also part of this study. The change in Magnetic Field will change the viscosity as shown in table 2.

Table 2: Effect of Magnetic Field on Dynamic Viscosity

Magnetic Field in Gauss	**Dynamic Viscosity in centi Poisse**
0	**6650**
100	**8340**
250	**12010**
550	**16000**
700	**22050**
1000	**22700**

3. Modeling with COMSOL

MR fluid damper modeled with its main components: damper cylinder housing, piston rod, piston head, and viscous fluid in the chamber. There is a small annular gap located at piston head. This works as an effective channel for the fluid. As the piston head moves back and forth inside the damper cylinder, fluid is forced to pass through the annular gap with large shear rate. By using provided dimensions, axially symmetric nature of the MR fluid damper and model it in a 2D-axisymmetric geometry as shown in Figure 3.[2-3]

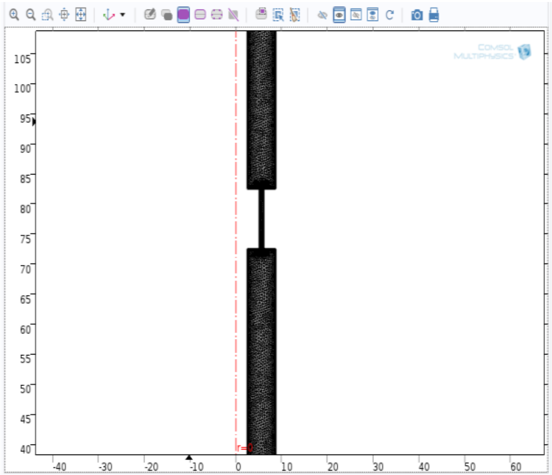

Figure 3: Geometry and mesh. The domains (from left to right) represent: piston rod, piston head and damping fluid gap, the cylinder outer wall

The fluid flow in the fluid damper is given by the weakly compressible Navier-Stokes equations, solving for the velocity field u = (u, w) and the pressure p:

$$p\frac{\partial u}{\partial t} + p_u \Delta u = -\nabla p + \left(\mu\left(\nabla u + (\nabla u)^T\right) - \frac{2}{3}\mu(\nabla u)I\right)$$

$$\frac{\partial p}{\partial t} + \nabla.\left(p_u\right) = 0$$

4. Result and discussions:

Simulation of two cases is done with using COMSOL Multiphysics. First simulation is based on change in MR fluid gap and second is based on change in magnitude of magnetic field i.e. change in viscosity.

4.1 Fluid Gap Analysis:

In order to execute the fluid gap analysis is necessary to describe two different kinds of materials: the iron and the magneto-rheological fluid. For both this kind of material it is possible to get the velocity and pressure distribution along the damper duct as given in Figure 4 and 5.

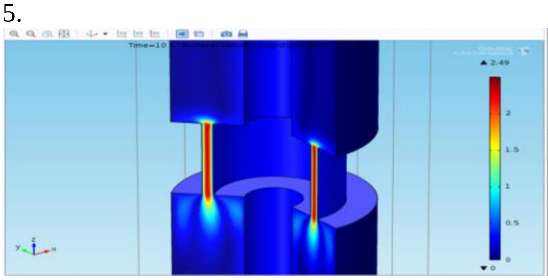

Figure 4: Velocity distribution over MR fluid gap at Piston head

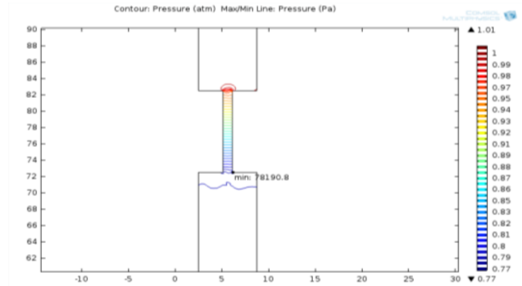

Figure 5: Pressure distribution over MR fluid gap at Piston head

Result obtained by varying in MR fluid gap it is observed that as gap increases velocity and pressure drop decreases.

Table 3: Change in velocity and pressure gap at various gap

MR Fluid Gap In mm	Velocity (m/s)	Pressure drop(atm)
1	2.47	1.87
2	1.56	1.49
3	0.63	1.09

4.2 Effect of Change in viscosity

When magnetic field is increased the viscosity of MR fluid is also increased as mentioned in table 1. In order to compute electromagnet Analysis, value of viscosity given in table no.1 are put in the equation. In this way the cylinder around the damper is set in the space and it is possible to analyze the damper behavior only by moving the fluids on the reverse direction of the shaft. By knowing the pressure drop in the chamber and the piston area of the damper one can calculate the force applied directly on the piston shaft. With the results got from this simulation at different viscosities, as shown in figure 5. it is possible to compare the force value obtained with COMSOL with the experimental results are almost the same. The model and procedure is validated by the result we got. So It is possible to design semi active damper by different orientations.

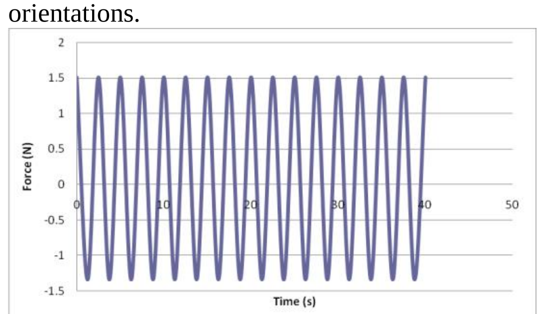

Figure 6 : Damping Force Vs Time plot

5. Conclusion:

In this problem concentration is given on the MR fluid gap at the piston head. Simulation is done by using COMSOL for such case by changing gap diameter. The velocity and pressure drop are decreases as gap increases. In next case value of viscosities are changed which happened due to change in magnetic field. It becomes convenient to estimate damping force at different viscosities which are changed under magnetic field due to simulation in COMSOL. It also makes it correct to simulate various configuration of dampers

6. References

1. 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

2. .Peel .J., Stanwa, R., Bullough W.A., "Design Optimization of a Controllable Vibration Damper for Vehicle Suspension Applications" *Active Control of Vibration and Noise, American Society of Mechanical Engineers, Design Engineering Division Publication, DE-Volume* 93, 1996, pp. 205-214.

2. Y.K. Lau e W.H. Liao, "Design and analysis of magneto-rheological dampers for train suspension"*Journal of Rail and Rapid Transit,219 (2005), pag. 261-276.*