Design and Fabrication of Eddy Current Damper

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Abstract - *ECD is Eddy current damper used to restrict motion via Eddy current damping. It reports an improved method that assures less maintenance, eco-friendliness and also contributing in heavy load applications. In this, eddy current loops are generated and energy is dissipated, thus producing a damping effect. This setup will make use of oil as the working fluid for amplification of the velocity of piston and the cylinder arrangement. A Copper cylinder is included in the setup to generate eddy current when it is passed through magnetic field which is generated by permanent magnets. Damping force will be observed at double acting cylinder. Tubes are equipped to connect double acting cylinder to another double acting cylinder which carries the Copper cylinder. In this way a more economical damping system with variable damping ratio can be achieved. Problems arising like fixed damping constant and frequent change of oil can be tackled. Damping can be easily varied thus making it a high performance damper.*

Key Words: ECD, double acting, damping ratio, heavy load applications, high performance

1. INTRODUCTION

Eddy currents are electric currents induced in a conductor when it is exposed to a changing magnetic field either due to the relative motion of the field source and conductor or due to the variations of field with time. These eddy currents circulate inside the body of the conductor which induce magnetic field of polarity opposite to the applied magnetic field [7]. Due to the internal resistance of the conductive material, eddy currents will dissipate kinetic energy into heat and energy will be removed from the system, producing a damping effect [7]. By using the concept of eddy current for damping purposes majority of research in eddy current damping has taken place [6].

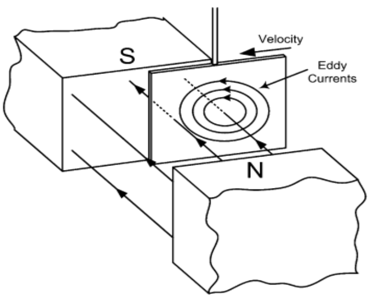


Fig -1: Schematic of conductive material passing through a magnetic field and the generation of eddy currents [8].

2. AIM AND OBJECTIVES

2.1 Aim

The aim of the project is to design and fabricate eddy current damper.

2.2 Objectives

The objectives that are inevitable and essential for completing our study of Eddy current damper are as follows:

- To calculate magnetic flux and eddy current damping force.
- To design high performance damper and to vary the damping easily.

3. PROBLEM DEFINITION

To design and fabricate an eddy current damper with the following specifications:

- Variable damping constant.
- High Reliability.
- High Thermal Stability.

4. SIMULATIONS PERFORMED

Simulation is the imitation of any real world phenomenon by developing a model, applying real world condition. The aim of the performed simulations is to determine the magnetic flux and eddy current damping force.

4.1 Quickfield Student

The geometry drawing is made in axisymmetric mode. Two nearby magnets brown in color are separated by a spacer and their poles are arranged in opposite direction.

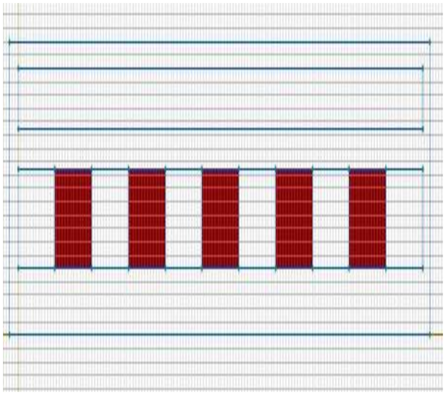


Fig -2: Geometry of magnet and spacer arrangement

Meshing of geometry is done in this step. The circles represent the size of mesh at that point.

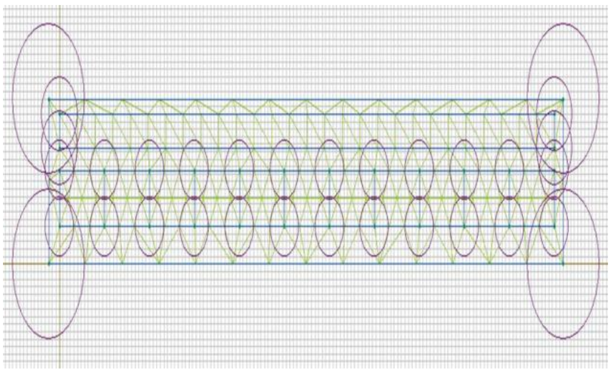


Fig -3: Meshing of geometry

Plot of magnetic field lines and magnet flux density is determined.

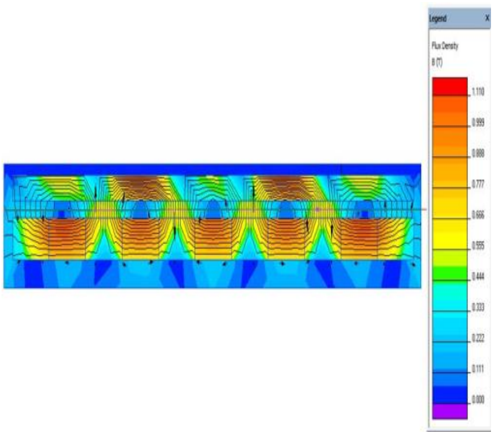


Fig -4: Plot showing magnetic field lines and magnetic flux density

Variation of magnetic flux density along the axial line between the outside cylinder and magnet and spacer is determined.

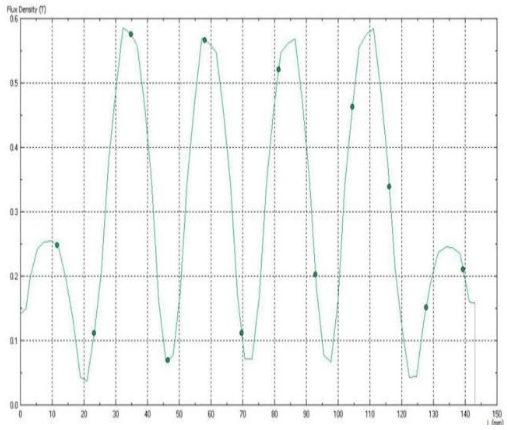


Fig -5: Plot of magnetic flux density along the axial line

Final results are obtained and average is calculated to find the average flux density.

L (mm)	r (mm)	B (T)
7.83236	14.5121	0.206133
15.6647	14.4743	0.217612
23.4971	14.4365	0.0407688
31.3295	14.3988	0.345511
39.1618	14.361	0.546453
46.9942	14.3232	0.230404
54.8265	14.2855	0.20991
62.6589	14.2477	0.54627
70.4913	14.2099	0.311931
78.3236	14.1722	0.145679
86.156	14.1344	0.516175
93.9883	14.0967	0.363323
101.821	14.0589	0.0677953
109.653	14.0211	0.483629
117.485	13.9834	0.469536
125.318	13.9456	0.0871637
133.15	13.9078	0.161409
140.983	13.8701	0.175057

avg B(T) =	0.293183

Fig -6: Magnetic flux density values

4.2 Comsol Multiphysics

The solution obtained for magnetic flux density are shown and compared with Quickfield Student.

The geometry drawing is done in axisymmetric mode. The geometry of magnet and spacer arrangement and copper tube is made.

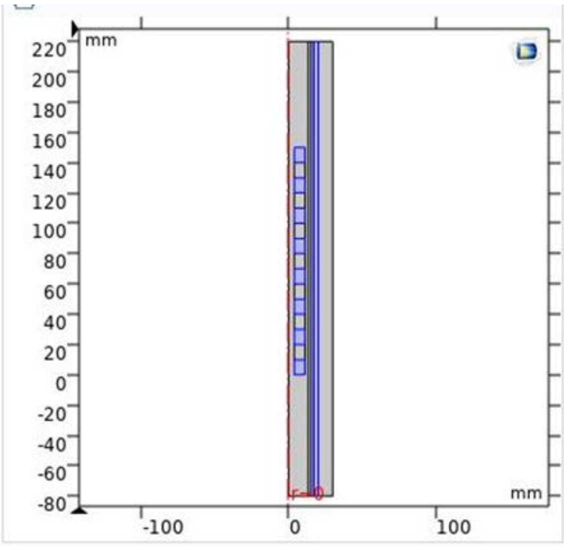


Fig -7: Geometry of the model

Meshing of geometry is done. The pattern made represent the size of mesh at that point.

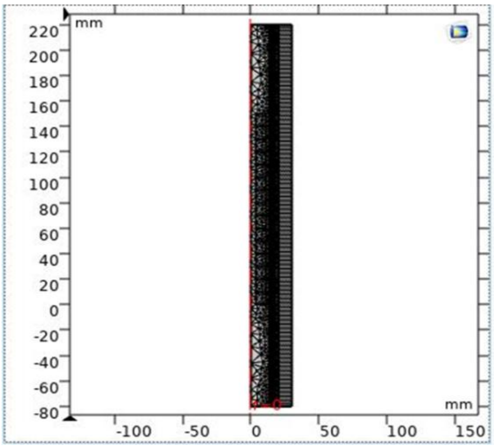


Fig -8: Meshing of the model

The results of eddy current damper simulation are obtained. These results are obtained in order to compare the same with the experimental values. Plot showing magnetic flux density in Tesla is obtained for the geometry made.

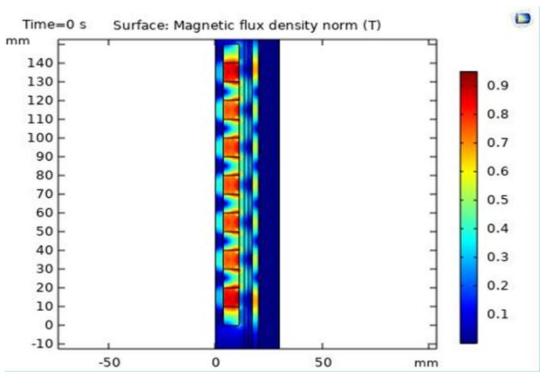


Fig -9: Plot showing Magnetic flux density

Eddy current induced in copper tube due to moving magnet is obtained as simulation results. Plot showing current density in Ampere per meter square is obtained for the geometry made.

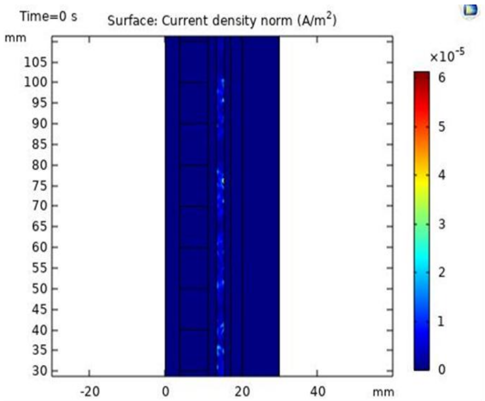


Fig -10: Plot showing current density

Lorentz force is induced in magnet due to eddy current formed in copper tube. Plot of Lorentz force in Newton versus Time in second is obtained. From this graph it is observed that the force reaches 450 N and returns to its initial value. This same curve is repeated at certain time intervals.

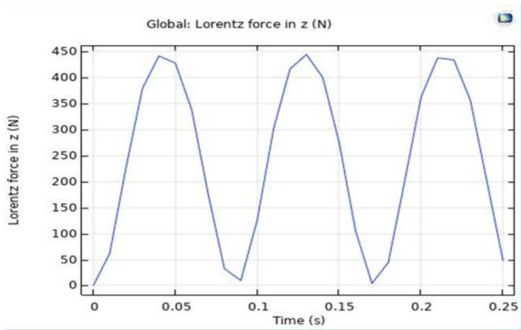


Fig -11: Plot of Lorentz force v/s time

Acceleration of falling magnet reduces as eddy current formed oppose the motion of magnet. Plot of magnetic acceleration in meter per square second versus time in second is obtained. From this graph it is observed that it reaches -350 m/s2 and returns to the initial value. This same curve is repeated at certain time intervals.

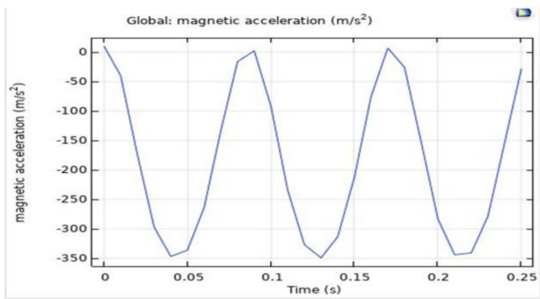


Fig -12: Plot of magnetic acceleration v/s time

Plot of velocity in meter per second versus time in second is obtained. From this graph it is observed that its velocity reaches 6 m/s and returns to its initial value. This same curve is repeated at certain time intervals.

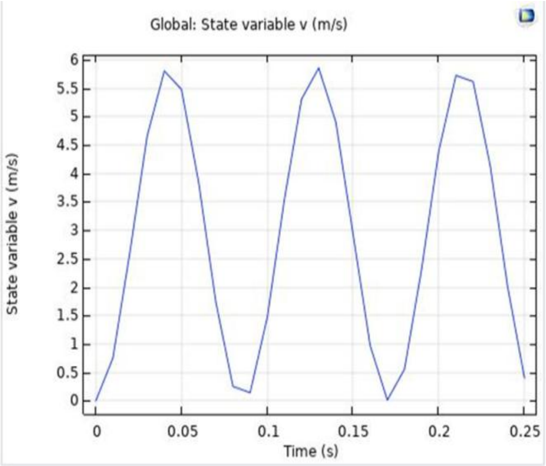


Fig -13: Plot of velocity v/s time

5. CONSTRUCTIONS

There are two double acting hydraulic cylinders of diameter in ratio (D/d=1) as shown in fig. Both the cylinders are connected by hose pipes. Oil is being used in the cylinder. The cylinders are kept virtually on a base. There is a magnet and a spacer arrangement where they are kept alternatively. The copper is also placed inside the steel casing and is attaches to the top of the second cylinder.

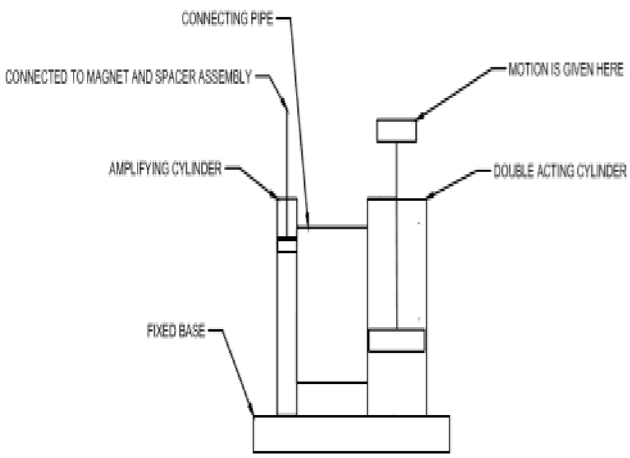


Fig -14: Schematic diagram of Eddy current damper

Fig -15: Eddy current damper setup

6. WORKING

External force is provided by the mechanical exciter of variable frequency and damping constant can be determined. As force is applied on the first cylinder, oil flows into the second cylinder causing the piston to move upward. As the piston moves upward the copper cylinder also reciprocates around the magnet and stator arrangement. Because of this eddy current is generated and a force opposite to the direction of movement of the cylinder is generated because of which damping occurs.

7. RESULT

A table of angular frequency, acceleration, velocity is plotted for various frequencies.

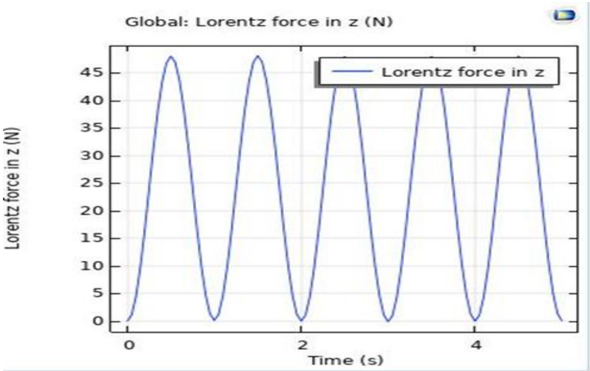
Following formula are used to obtain the values:

f = frequency (Hz)
ω = angular frequency = 2πf (rad/s)
a = acceleration = $\omega^2 R$ (rad/s^2)
v = velocity = Rω (m/s)

Table -1: Angular Frequency, Acceleration and Velocity for Various Frequencies

Frequency	Angular frequency (ω)	Acceleration ($\omega^2 R$)	Velocity (ωR)
0	0	0	0
1	6.28	1.57	0.251
2	12.56	6.31	0.502
3	18.84	14.21	0.75
4	25.13	25.26	1.005
5	31.41	39.47	1.256
6	37.7	56.84	1.508
7	43.98	77.37	1.75
8	50.26	101.06	2.01
9	56.54	127.91	2.26
10	62.83	157.91	2.51
11	69.11	191.07	2.76

Taking various values from the table, different graph of Lorentz force v/s time are plotted.



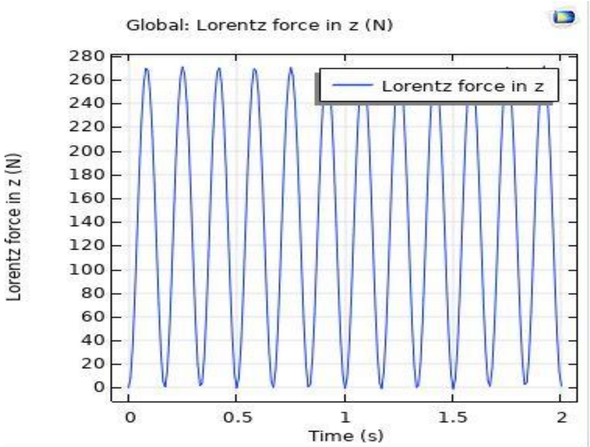


Fig -16: Graphs for Lorentz force v/s Time

It is observed that the Lorentz force varies sinusoidal in nature. This is because the motion of the magnets is simple harmonic motion. From the graph we come to know the value of Lorentz force acting at any particular frequency. Because of the arrangement of the setup whatever force acts on the copper tube two times of that force acts on the upper plate therefore the graph is plotted where we take maximum force instead of mean force. The graph showing force acting on the upper plate of damper at different operating frequencies of the setup is shown.

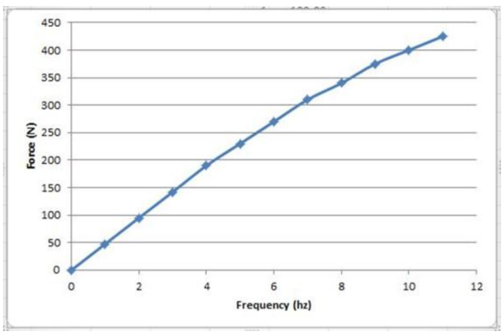


Fig -17: Graph of Force v/s Frequency

From maximum force acting we can calculate damping constant by the formula C = F/v where, f is obtained from the graph and v = Rω. The graph is plotted as shown.

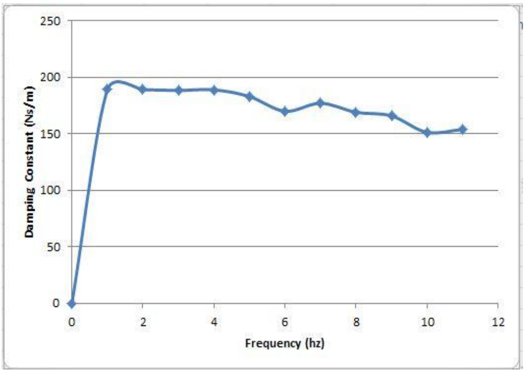


Fig -18: Graph of damping constant v/s Frequency

8. CONCLUSION

An Eddy current damper has been designed; novel feature of this design is incorporation of fluid amplification link to increase relative velocity between magnet and copper tube. Fabrication and simulation has been done successfully. The initial design was modified so as to achieve structural rigidity and avoid over-damping. The damper was designed such that it could be tested on the mechanical exciter [23]. Because of the values obtained in theoretical calculation, double acting hydraulic cylinder with higher operating pressure was procured and by testing the damper led to complications in requirement of mass for the working of spring-mass damper system. Hence the results obtained by the simulation couldn't be verified by testing the damper. The simulation of magnetic flux density was carried out in Quickfield Student and was later compared with the simulation done on COMSOL Multiphysics. The result obtained showed almost similar values. The result for various damping constant can be easily inferred through damping constant v/s frequency graph.

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