

Design and analysis of Electromagnetic Inerter

Adish Joshi¹, Atharva Jadhav², Chinmayi Bhagwat³, Smit Talekar⁴, Varad Ghathe⁵

^{1,2,3,4,5} Department of Mechanical Engineering, Walchand College of Engineering, Shivaji University, Sangli, India

Abstract - The main objective of a car suspension system is to improve the ride comfort without compromising the ride handling characteristic. The suspension system reduces the effect of vibration caused by the road and driving conditions. Over recent years the massive developments have made intelligent suspension systems more feasible to implement in automobile industry. But these suspensions possess some disadvantages such as vibration, mechanical failure and stiffness variation. So, through this project we highlight the idea of "ELECTROMAGNETIC INERTER" which will enhance the driving pleasure and control over road. Inerter suspension will allow us to get variable stiffness and much higher comfort just by playing with magnetic field. It will also allow us to reduce wear and tear along with less maintenance. The report also compares different types of inerter in the suspension, such as mechanical & electromagnetic, and optimizes the inertance and damping parameters for certain road conditions. This report uses a two-degree-of-freedom quarter vehicle model to simulate and analyze the suspension responses.

Key Words: Electromagnet, Eddy Current, Damping, Inerter

1. INTRODUCTION

The Electromagnetic Inerter Damper, which acts as both a spring and a damper to efficiently regulate dynamic forces, marks a paradigm leap in vibration control technology. This new gadget has the potential to have a big influence in businesses where accurate vibration control is critical. The project's goal is to use electromagnetic principles and sophisticated control algorithms to develop a flexible and adaptable system capable of suppressing vibrations across a wide frequency range. The introduction lays the groundwork for a thorough examination of the design and development process, emphasizing the relevance of the Electromagnetic Inerter Damper in addressing the changing needs of varied engineering applications. The next sections will go into the technical elements of the system architecture, electromagnetic design, control techniques, and the rigorous testing and validation processes used to assure the efficacy and dependability of this revolutionary technology.

2. Mechanical Inerter

The inerter is a device that uses the energy from the oscillation against the spring's oscillation, rather than just

dissipating it. It consists of a lead screw and a flywheel. When a force is applied to one end of the rod, it pushes up through the flywheel, causing it to spin. This conversion of linear energy into rotational energy helps counteract the spring's oscillation. Once the force is no longer applied, the momentum of the flywheel is returned back into the rod, making it want to continue in that direction. This helps reduce the oscillation of the spring and improves the stability of the car.

When we plot the force of the inerter acting on the spring, we observe a wave-like pattern. Some dampening occurs due to the initial start-up of the flywheel spinning, but the significant dampening occurs when the spring rebounds.

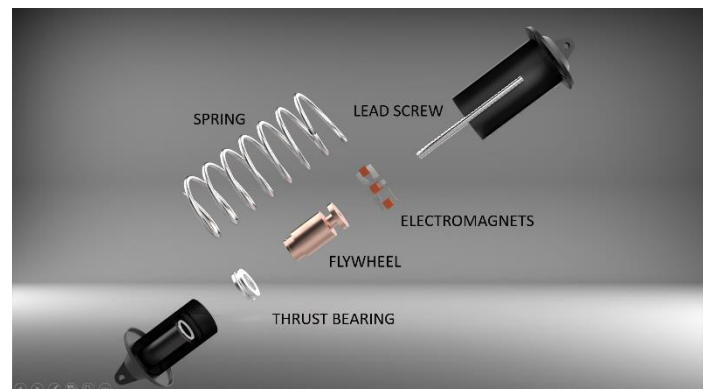


Fig -1: Exploded View of Assembly

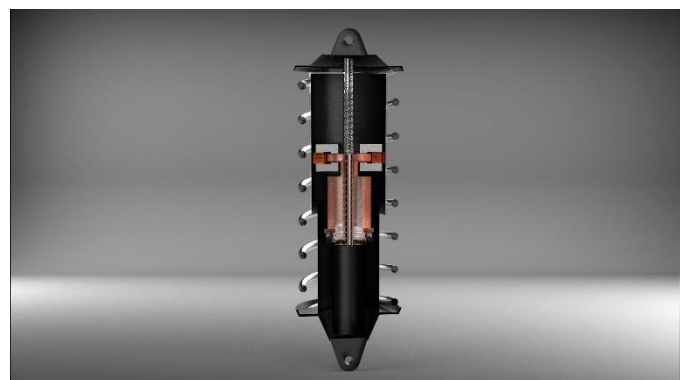


Fig -2: Section View of Assembly

3. Calculations -

3.1 Parameters for the calculations -

Table 1 -

Property	Value	Unit
Accel.	3.33	m/s ²
C.G. height	0.5	m
Sprung mass	210	kg
Unsprung mass	36	kg
Total mass	1100	kg
Wheelbase	2.5	m
Weight distribution	0.6	
Frictional coefficient	0.8	

3.2 Calculated data -

Table 2 -

Parameter	Value	Unit
Bump force	6529.52	N
Torque to move load	7.38	Nm
Helix angle	42.19	Degree
Torque on flywheel	4.1	Nm
Magnetic flux density	0.0165	T
Current flowing through conductor	28	A

4. Analysis

The suspension system is designed for a quarter car model (one of the four wheels) which is used to simplify the problem of two degrees of freedom system to a 1-D multiple spring-damper system. This system is then compared to a system of standard spring mass damper. Using the mathematical blocks in MATLAB SIMULINK, we have done an analysis based on the dynamic equations of the suspension system of the quarter car model to analyze the effect of the mechanical and electromagnetic inerter on the response of the suspension system.

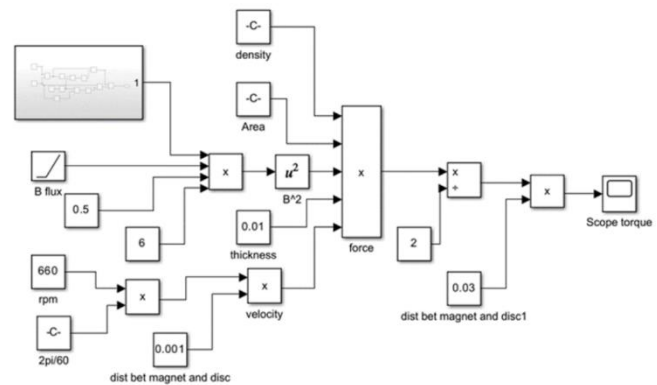


Fig -3: Main system simulink model

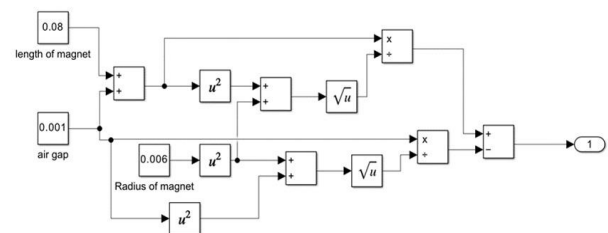


Fig -4: Main system simulink model

1] For load 4500 N load (200 kg load on quarter car model):

1. Spring Mass Damper system (Blue line in graph):

Maximum Displacement- 63 mm

2. Spring Mass Damper Inerter system (Red line in graph):

Maximum Displacement- 58 mm

3. Spring Mass Electromagnetic Inerter system (Green line in graph):

Maximum Displacement- 45 mm

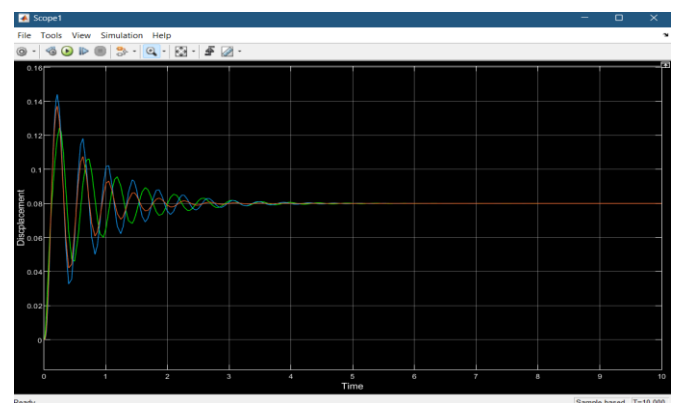


Fig -5: Case 1

2] For load 6500 N load (275 kg load on quarter car

model):

1. Spring Mass Damper system (Blue line in graph):

Maximum Displacement- 65 mm

2. Spring Mass Damper Inerter system (Red line in graph):

Maximum Displacement- 60 mm

3. Spring Mass Electromagnetic Inerter system (Green line in graph):

Maximum Displacement- 52 mm

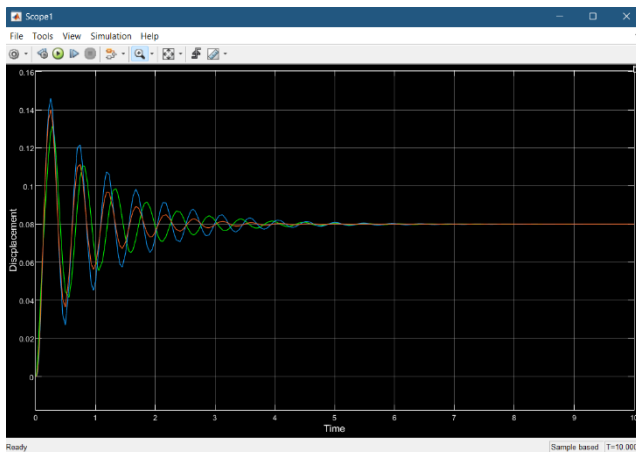


Fig -6: Case 2

3] For load 8000 N load (360 kg load on quarter car

model):

1. Spring Mass Damper system (Blue line in graph):

Maximum Displacement- 70 mm

2. Spring Mass Damper Inerter system (Red line in graph):

Maximum Displacement- 62 mm

3. Spring Mass Electromagnetic Inerter system (Green line in graph):

Maximum Displacement- 55 mm

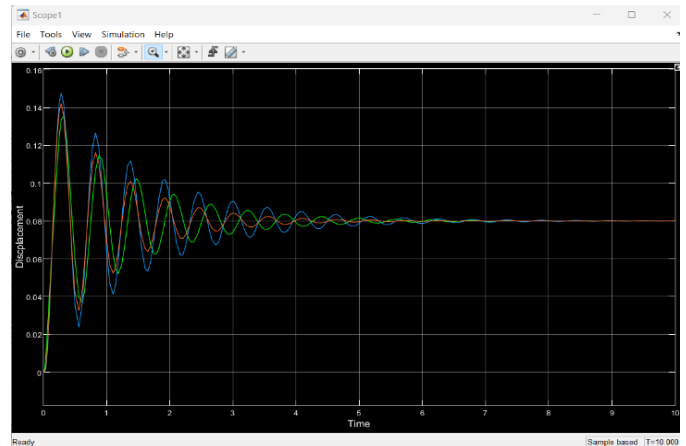


Fig -7: Case 3

• **Structural analysis of lead screw –**

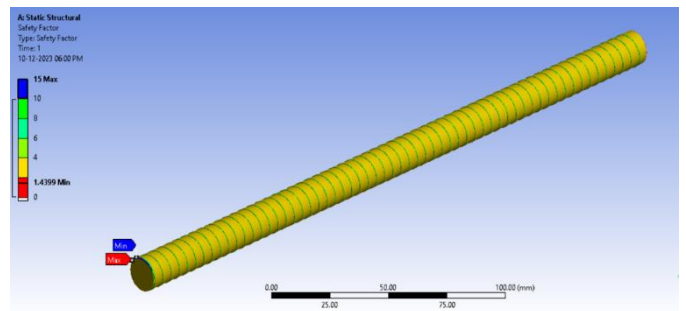


Fig -8: Safety factor under maximum loading condition

A static structural analysis of the lead screw in the system was conducted. A conservative force of 12,000 N was applied, 30% higher than the damper's maximum force. The analysis showed a minimum factor of safety (FOS) of 1.43, confirming the screw's structural integrity. The results affirm the lead screw's reliability and safe operation under expected conditions.

• **Modal frequency analysis –**

The modal analysis resulted in the identification of the first 6 natural frequencies and their corresponding mode shapes. The results are summarized in a table below:

Mode	Frequency [Hz]
1	29.009
2	29.287
3	220.79
4	325.82
5	327.62
6	911.05

Since the system operates at 660 RPM (11Hz) and it is not near any of these frequencies, we can conclude that resonance is successfully avoided.

4. CONCLUSIONS

By changing the magnitude of force applied on damper according to the change in velocity by which a vehicle is approaching the bump the values of displacement from the mean position for the velocity of 10 Km/hr, 30 Km/hr and 50 Km/hr are tabulated below. The values are taken from simulating respective mass and force parameters on MATLAB Simulink.

The results to be tabulated as:

Table -1: Displacement variation by loads

Velocity (Km/hr)	Load (N)	Spring Mass Damper (mm)	Mechanical Inerter (mm)	Electro magnetic Inerter (mm)
10	4500	63	58	45
30	6500	65	60	52
50	8000	70	62	55

In conclusion, the data clearly demonstrates that the electromagnetic inerter offers a superior vibration control solution compared to conventional methods. Lower displacement across various velocity conditions, along with the ability to address resonance issues, make it a promising technology for enhancing structural stability and protecting equipment from vibration-induced damage.

REFERENCES

- [1] Sarthak Vaishnav, "Model development and simulation of vehicle suspension system with magneto-rheological damper" IOP Conf. Ser.: Earth Environ. Sci. 850 012035.
- [2] Pranav Teli , Vinayak Tamhankar , Suyash Zagade , Aniket Suvre, "Study of Electromagnetic Damper" Paper ID : IJERTV8IS090197.
- [3] Alexei Filatov, Larry Hawkins, "Active Radial Electromagnetic Damper", Conference: 2019 IEEE International Electric Machines & Drives Conference (IEMDC)
- [4] Nabeel Alshabat, Tamir Shaqarin, "Impact of Using an Inerter on the Performance of Vehicle Active Suspension" July 2022 Advances in Science and Technology - Research Journal 16(3):331-339

- [5] Sneha Chavan, Chinmay Soni, Yashraj Zanwar , Rutuja Phatangare, "Design and Fabrication of Eddy Current Braking System". 2019 JETIR April 2019, Volume 6, Issue 4