Experimental Investigation of Damping characteristics for various Damping Materials

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Abstract - *The basic purpose of damper is to reduce the vibration and to have a better comfort and safety. The characteristic of damping system has an important influence on its design and overall performance of the system. In this paper magnetic damping effect is considered for characterization. Hence in order to design damping systems determination of damping coefficients is necessary. This effect is the most recently used due to their low price and high reliability. An experiment has been conducted to establish the behavior of magnetic damper. The damping materials are water, magnet and SAE 40 grade oil used for characterizing the vibration behavior. The amplitude Verses frequency response curves are plotted for above damping materials. .*

Key Words: **Damping coefficient, Frequency ratio, Amplitudes, Natural frequency**

1. INTRODUCTION

Damping can be defined as dissipation of oscillating energy. Oscillating energy includes vibration, noise and shock waves. Passive suspension systems are most commonly used damping systems because of their low price and high reliability.

The goal is to investigate characteristics of the damper for a single degree of freedom system, analyses under harmonic excitation of the base. The magnetic dampers are now being effectively deployed as vibration dampers in the suspension system to enhance the comfort and safety.

The damping in a system can be obtained from free vibration decay curve. Where the free vibration test is not practical, the damping may be obtained from the frequency response curve of forced vibration test.

Fischer and Isermann[1] have shown how each part in a vehicle suspension use as ride comfort in dynamic model. Lin and Kanellakopoulos[2] shows system can have dual purpose of comfort and safety. Xu shows[3] how vibration of parts can effect the mechanism. Ebrahimi, Khamesee and Golnaraghi [4] demonstrate passive damping can be achieved by addition of viscous fluid to the active damper, which guaranties a failsafe damper in case of power failure. The electromagnetic dampers have lesser reliability because of dependence on external power source and higher weight. Lee, Park, Min and Chung[5] shows how to control seismic response of building structures using tuned liquid damper. Yau and Chen[6] shown vibration suppressing system using electric- hydraulic actuator design using squeeze film damper. Lee and Jee[7] the vibration of a flexible cantilever beam using active piezoelectric type servo damper to suppress both small and large amplitude vibrations. Martins et al[8]proposed a new hybrid damper design for vehicle suspension application. Linear actuator was the active unit and the hydraulic passive damping effect as a passive part. Lin and Roschke and Loh [9]proposed a hybrid base isolation with MR dampers, and showed that a combination of high damping rubber bearing isolators and MR damper can provide robust control of vibration for large civil engineering structures from a wide range of seismic events**.**

2. MODELING OF FABRICATED DAMPER AND EXPERIMENTAL SET UP

A beam made of mild steel having rectangular cross section with dimensions 20mm X 8 mm and length of 760 mm. One end of the beam is hinged and the other end is connected to frame using a spring. An exciter is placed on it at 460 mm from the hinged end. A DC motor of capacity 1800 rpm with a mass of 8.5kgs and disc connected to the shaft with eccentric masses 0.15kg. DC motor is used as exciter. Speed control device is used for control the speed of DC motor which generates vibration for system range (0-1800 rpm). A mechanical recording device is mounted on frame which records the amplitude of vibration of system.

The cantilever structure with attached mass is the most widely used configuration for spring mass device. The stiffness of the structure depends on the loading condition, material, and cross sectional area perpendicular to the direction of vibration. Passive system is the most used type in automobile suspensions. The main reasons are the simplicity, low cost and reliability of this solution. A spring and damper compose this suspension system, both fixed between the wheel supporting structure (unsprung mass) and the beam (sprung mass).

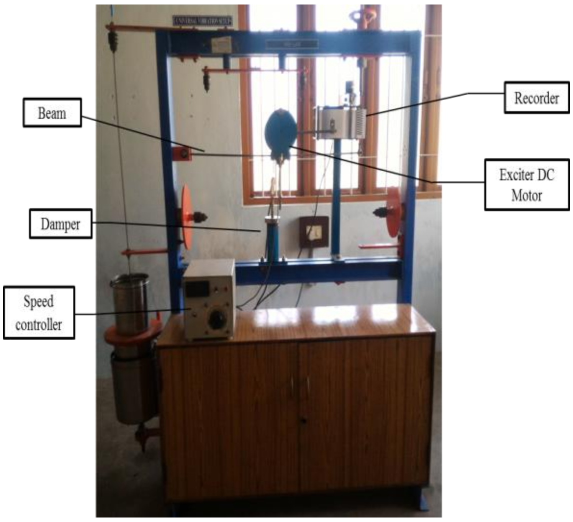


Figure - 1. Experimental Setup

2.1 Magnetic Damper

Two permanent magnets of diameter 5cm are taken one magnet is fixed to the cylinder at bottom and other magnet is connected to the system top surface. The cylinder and piston is arranged like such that poles of the both magnets are faced together. When beam vibrates the beam pushes the piston downwards. When the piston comes nearer to the cylinder bottom surface due to like pole magnet fixed at the bottom surface a repulsive force exerts on the piston. This automatically controls the level of vibration.

The damping coefficient is found for this magnetic damper through the experiment and it is compared with the other existing dampers.

3. Analytical Formulae

The governing equation of motion of spring mass system

$$m\ddot{x} + c\dot{x} + k=0$$

In the case of cantilever beam we first calculated moment of inertia of the beam by taking length, thickness, and width of the beam. Moment of inertia for a rectangular cross-section can be obtained from the expression

Moment of inertia for the beam

$$I = \frac{bd^3}{12}$$

Using mass equivalent and stiffness of beam and spring, we can calculate natural frequency of the system having Static deflection of 25mm.

Mass equivalent of the system $m_{eq} = M_0 * \frac{l_1}{l}$

Spring stiffness $k_{spring} = \frac{m_{eq} * g}{\delta_{st}}$

Beam stiffness

$$k_{beam} = \frac{1}{\frac{l1^3}{3EI}+\frac{l1^2}{2EI}(l-l1)}$$

Equivalent stiffness $k_{eq} = k_{spring} + k_{beam}$

Natural frequency of the system $\omega_n = \sqrt{\frac{k_{eq}}{m_{eq}}}$

Angular velocity of the system $\omega = \frac{2\pi N}{60}$

Harmonic force is given to the beam via exciter. The time period is noted based on the time period the damping coefficients are determined. Experimental values of time period for damped oscillation system T_d observed.

Damped natural frequency of the system

$$\omega_n = \frac{2\pi}{T}$$

$$\omega_d = \frac{2\pi}{T_d}$$

$$\omega_d = \omega_n \sqrt{1 - \zeta^2}$$

From above equation we calculated ζ, then we calculate damping coefficient

Damping coefficient $\zeta = \frac{c}{c_c}$

The steady state amplitude 'X'

$$\frac{X}{(\frac{m_0 * e}{m})} = \frac{(\frac{\omega}{\omega_n})^2}{\sqrt{[1 - (\frac{\omega}{\omega_n})^2]^2 + [2\zeta\frac{\omega}{\omega_n}]^2}}$$

At various static deflections of the beam the amplitudes of vibrations have found. The damping coefficients (ζ) are found using static deflections.

Table -1: Damping Coefficients at different deflections

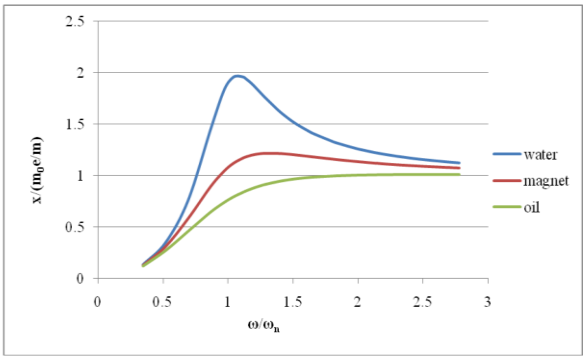
Damping materials	Deflections in mm				Average ζ values
	25	**20**	**15**	**10**	
Water	0.33	0.273	0.24	0.211	0.2635
Magnet	0.5329	0.4841	0.4687	0.3715	0.4643
SAE 40 oil	0.8012	0.7695	0.6513	0.4100	0.657

4. Results and Discussion

The Natural frequency of the system is 30.1475 rad/sec.

Table- 2: Speed, frequency ratio, Dimensionless amplitude values for Water, Magnet and Oil

Speed in rpm	ω	ω/ω_n	$x/(m_o e/m)$		
			Water	**Magnet**	**Oil**
100	10.472	0.347	0.134	0.128	0.121
150	15.708	0.52	0.348	0.31	0.271
200	20.944	0.694	0.76	0.583	0.459
250	26.179	0.867	1.45	0.893	0.645
280	29.321	0.972	1.835	1.044	0.739
300	31.415	1.041	1.954	1.117	0.791
320	33.51	1.111	1.958	1.166	0.834
330	34.557	1.145	1.931	1.183	0.853
340	35.604	1.18	1.894	1.196	0.87
350	36.651	1.215	1.85	1.205	0.886
360	37.699	1.249	1.804	1.211	0.899
370	38.746	1.284	1.758	1.214	0.912
400	41.887	1.388	1.631	1.213	0.941
420	43.982	1.458	1.559	1.207	0.956
440	46.076	1.527	1.498	1.198	0.968
470	49.218	1.631	1.422	1.183	0.981
480	50.265	1.666	1.401	1.178	0.984
520	54.454	1.805	1.329	1.158	0.994
530	55.501	1.84	1.314	1.153	0.996
570	59.69	1.978	1.264	1.136	1.002
590	61.784	2.048	1.244	1.128	1.004
610	63.879	2.117	1.225	1.12	1.005
620	64.926	2.152	1.217	1.117	1.006
630	65.973	2.187	1.209	1.113	1.006
660	69.115	2.291	1.188	1.104	1.008
670	70.162	2.326	1.182	1.101	1.008
710	74.351	2.465	1.159	1.091	1.009
770	80.634	2.673	1.133	1.078	1.009
800	83.775	2.777	1.122	1.072	1.009

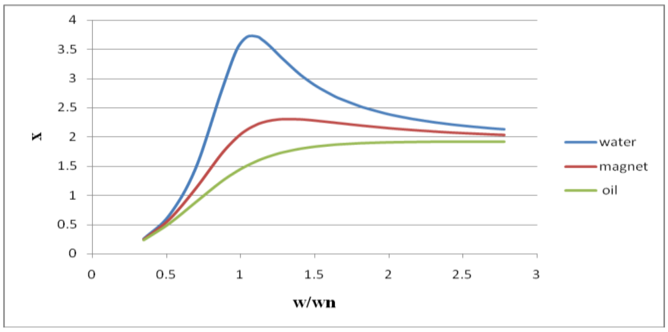


Graph- 1: Dimensionless amplitude v/s Frequency ratio for combined Water, Magnet and Oil

Table-3: Speed, Frequency ratio, amplitude values for water, magnet and oil

Speed in rpm	ω	ω/ω_n	X in mm		
			Water	**Magnet**	**Oil**
100	10.472	0.347	0.254	0.244	0.23
150	15.708	0.52	0.66	0.588	0.514
200	20.944	0.694	1.442	1.105	0.871
250	26.179	0.867	2.751	1.695	1.224
280	29.321	0.972	3.481	1.982	1.402
300	31.415	1.041	3.707	2.119	1.5
320	33.51	1.111	3.715	2.213	1.583
330	34.557	1.145	3.664	2.245	1.619
340	35.604	1.18	3.593	2.269	1.651
350	36.651	1.215	3.51	2.286	1.68
360	37.699	1.249	3.423	2.297	1.707
370	38.746	1.284	3.336	2.304	1.73
400	41.887	1.388	3.095	2.302	1.786
420	43.982	1.458	2.958	2.29	1.814
440	46.076	1.527	2.842	2.273	1.836
470	49.218	1.631	2.698	2.245	1.861
480	50.265	1.666	2.657	2.235	1.868
520	54.454	1.805	2.522	2.197	1.887
530	55.501	1.84	2.494	2.188	1.89
570	59.69	1.978	2.398	2.155	1.901
590	61.784	2.048	2.359	2.14	1.904

610	63.879	2.117	2.325	2.126	1.907
620	64.926	2.152	2.309	2.119	1.908
630	65.973	2.187	2.294	2.113	1.909
660	69.115	2.291	2.254	2.095	1.912
670	70.162	2.326	2.242	2.089	1.912
710	74.351	2.465	2.199	2.069	1.914
770	80.634	2.673	2.149	2.045	1.914
800	83.775	2.777	2.129	2.034	1.914



Graph -2: Amplitude v/s Frequency ratio values for combined Water, Magnet and Oil

Table -4: Theoretical and Experimental amplitude values for Water

Water			
Speed in rpm	ω/ωn	X in mm	
		Theoretical	Experimental
250	0.867	2.751	2.5
280	0.972	3.481	3
300	1.041	3.707	3.5
350	1.215	3.51	3
400	1.388	3.095	2.8
470	1.631	2.698	2.5
530	1.84	2.494	2

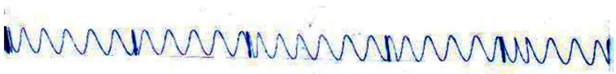


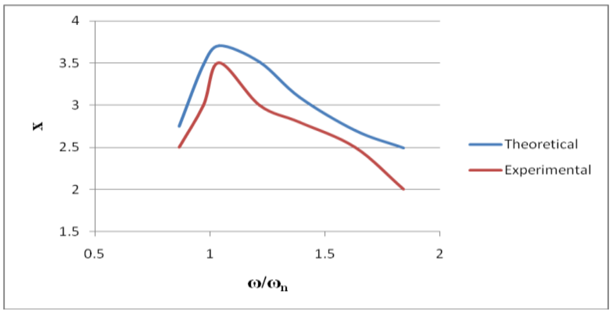
Fig.2a

Fig.2b

Fig.2c

Figure -2: Experimental amplitude values for water

Some of the experimental values of water at speeds 250(fig.2a), 350(fig.2b),470 (fig.2c)rpm and amplitudes 2.5mm, 3mm, 2.5mm respectively



Graph -3: Amplitude v/s Frequency ratio values for Water

Table -5: Theoretical and Experimental amplitude values for Magnet

Magnet			
Speed In rpm	ω/ωn	X in mm	
		Theoretical	Experimental
280	0.972	1.982	1.8
320	1.111	2.213	2
370	1.284	2.304	2.3
400	1.388	2.302	2.3
570	1.978	2.155	2
620	2.152	2.119	2

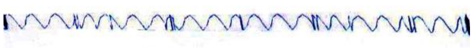


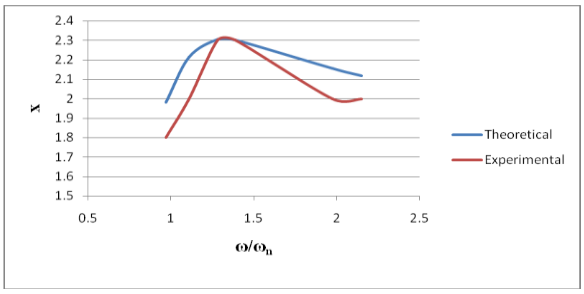
Fig.3a

Fig.3b

Fig.3c

Figure -3: Experimental amplitude values for Magnet

Some of the experimental values of magnet at speeds 280(fig.3a), 400(fig.3b),, 620(fig.3c) rpm and amplitudes 1.8mm, 2.3mm, 2mm respectively.



Graph -4: Amplitude v/s Frequency ratio values for Magnet

Table -6: Theoretical and Experimental amplitude values for Oil

Oil			
Speed In rpm	ω/ω_n	x in mm	
		Theoretical	Experimental
250	0.867	1.214	1
280	0.972	1.402	1
300	1.041	1.5	1.2
350	1.215	1.68	1.5
400	1.388	1.786	1.5
520	1.805	1.887	1.8
570	1.978	1.901	1.8

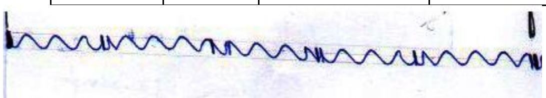


Fig.4a

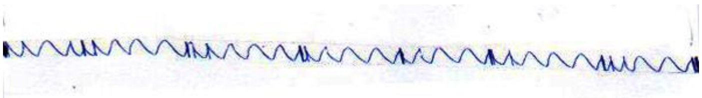
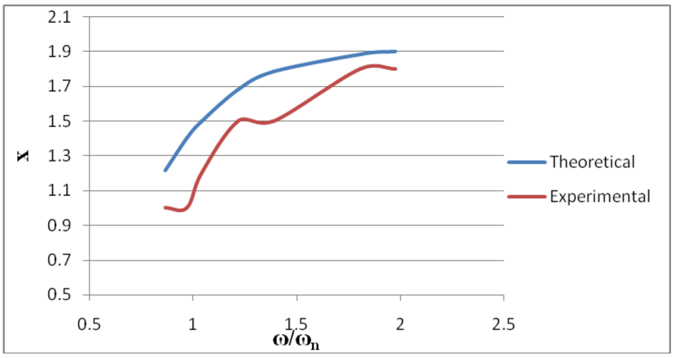


Fig.4b

Fig.4c

Figure -4: Experimental amplitude values for Oil

Some of the experimental values of oil at speeds 250(fig.4a), 350(fig.4b),570 (fig.4c) rpm and Amplitudes 1mm, 1.5mm, 1.8mm respectively.



Graph -5: Amplitude v/s Frequency ratio values for Oil

5. Conclusion

Damping characteristics for damping materials are observed. For all types of damping materials, same features of system were used and then analyzed. Experiment conducted on VIB-LAB equipment. Damping coefficient C, displacement amplitude x and frequency ω/ω_n are investigated. Damping ratio ζ value less than 1 hence this is under damped system.

Magnetic damper is proposed to suppress the vibrations at the free end of a cantilever beam. The experiment reveals that the proposed magnetic damper is effectively control the vibration. Variation of amplitudes of vibration at different speeds for the magnetic damper was found. The damping coefficient of the magnetic damper is C=143.96 Ns/m and Damping ratio ζ = 0.4643. After comparison of oil, water and magnet the one control of vibration lies between water and oil for the provided magnetic damper. Magnetic damper does not require lubrication and maintenance is less. Effectiveness of damper can be improved by providing electromagnetic damper.

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