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Study of Particle Damper to Supress Vibration of Beam Structure

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Abstract: Vibration is the oscillatory motion about its mean position. Vibration can be used for useful purpose as in vibration testing equipment, vibratory system, conveyors, hoppers etc. But vibration in some cases has disadvantageous too. In engines due to faulty design and poor manufacturing there is unbalanced force developed in rotating parts of engine, which causes vibration
The vibration dampers are frequently used to control and minimize excess vibration in structural system. Particle impact dampers are used to reduce the undesirable vibration in many applications.
This paper presents the result of an experimental study of the performance of granular material as a damper with lead ball having 1.72mm diameter and steel ball having 6.35mm and 3.97mm diameter respectively. It is observed that from experimental results, the granular material is supressed vibration of cantilever beam.
This paper focuses on Particle damping (PD) which is passive vibration damping technique in which particles lead (1.72mm) and steel (6.35mm and 3.97mm) are placed in the enclosure attached to the vibrating structure at highest amplitude region, in order to suppress vibration of primary structure. The collision between particle to particle and particle to wall results in exchange of momentum, hence energy dissipation takes place. Due to its simplicity and potential effectiveness over wide temperature range, and low cost makes PD a better substitute to conventional damping techniques. In order to study the damping effectiveness, a cantilever beam of aluminium is selected as machine member. The response (tip displacement) is measured by miniature accelerometer attached at free end of beam. Testing is performed on undamped beam, with particle dampers containing different size of steel spheres and lead particles.
By conducting the experiment it is observe that the use of lead particles and steel particles supress the vibrations amplitude considerably.

Keywords: vibrations, particle damping, enclosure, exiting force, response, accelerometer.

I. INTRODUCTION

Vibration is the motion of a particle or a body or system of connected bodies displaced from a position of equilibrium. The presence of unwanted vibrations in a structure must often be overcome to avoid damage and eventual failure due to high cycle fatigue. Many buildings ,bridges also fall due to vibration. Vibration can be used to for useful purpose as a vibration testing equipment's, vibratory conveyors, hoppers sieves, musical instruments and propagation of sound. But vibration in some cases disadvantageous too.
In engines due to faulty design and poor manufacturing, there is unbalanced force developed in rotating parts of engine, which causes vibration. Vibration causes rapid wear and tear of parts.

If excitation frequency coincides with natural frequency of main system a condition of resonance is reached and dangerously large oscillations may occur. This may result in mechanical failure of system.So keeping in view all these diverting effects, it is necessary to minimize vibrational effect over mechanical components. Undesirable vibrations may be eliminated or reduced by following methods

- Removing external excitation if possible
- Balancing – Force Reduction of inputs related to rotating components, such as unbalance, and rubbing will result in corresponding reduction of vibration response.
- Using vibration absorbers which control vibration by generating a force that opposes the excitation force of a resonant system. This is achieved using spring mass system that is tuned to have a system resonant frequency equal to frequency of excitation force.

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- Damping an external resistance using dampers is provided so as to reduce the vibrations through energy dispersion. The external resistance which is provided to reduce vibration is known as damping.

II. IMPACT DAMPING

`Impact dampers are designed to damp a specific frequency. There are two basic situations when vibration response is dominated by one frequency: the response results from either a resonance or mode at that frequency, or from a strong excitation at that frequency. One of the first applications was a impact damper for controlling aircraft flutter, fatigue, and vibration by Lieber and Jensen Impact damping is a passive vibration control technique that consists of an impactor operating in the cavity of a primary system. Each collision of the impactor with the wall of the cavity results in an exchange of momentum and some energy dissipation, producing attenuations of the response of the primary system. Due to the simplicity of their construction, impact dampers have been widely used for structural damping applications in skyscrapers, machine tools and other lightly damped structures. Impact dampers have also been considered for use in harsh environments such as turbo machinery blade, since their effectiveness is independent of the environment. A solid particle has conventionally been used as the impactor.

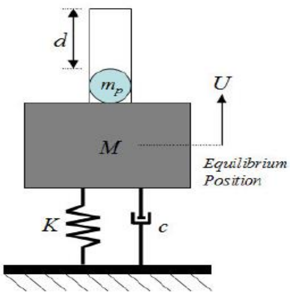

Fig.1 Model of an impact damper

III. PARTICLE IMPACT DAMPING

Active and passive damping techniques are common methods of attenuating the resonant vibrations excited in a structure. Active damping techniques are not applicable under all circumstances due, for example, to power requirements, cost, environment, etc. Under such circumstances, passive damping techniques are a viable alternative. Various forms of passive damping exist, including viscous damping, viscoelastic damping, friction damping, and impact damping.

Due to these limitations, attention has been focused on impact dampers, particularly for application in cryogenic environments or at elevated temperatures. Particle damping technology is a derivative of impact damping with several advantages. The literature typically distinguishes particle damping from impact damping based on the number and sizes of the auxiliary masses (or particles) in a cavity. As shown in the idealized single-degree-of freedom system, impact damping usually refers to only a single (somewhat larger) auxiliary mass in a cavity, whereas particle damping is used to imply multiple auxiliary masses of small size in a cavity

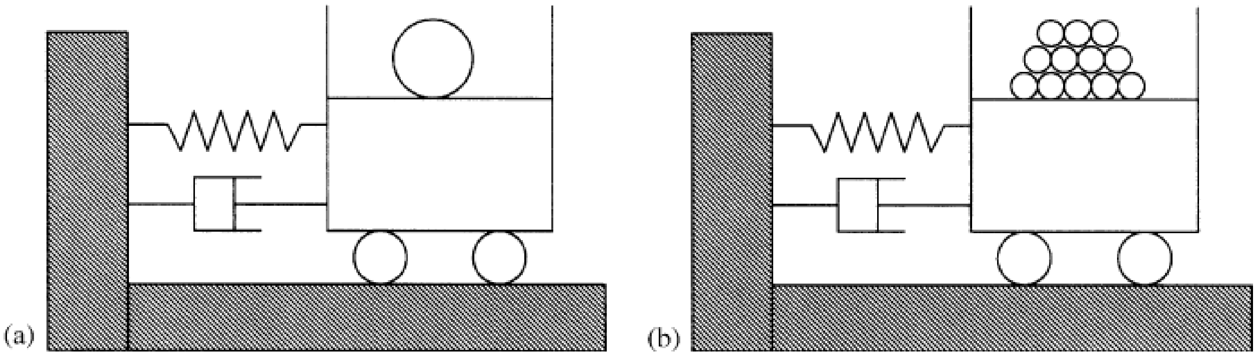

Fig.2 Idealized single-degree-of-freedom system with (a) impact damper and (b) particle damper

IV. DESIGN OF PRIMARY SYSTEM

For a cantilever beam subjected to free vibration, and the system is considered as continuous system in which the beam mass is considered as distributed along with the stiffness of the shaft, the equation of motion can be written as

$$\frac{d^2}{dx^2}\{EI(x)\frac{d^2Y(x)}{dx^2}\} = \omega_n^2 m(x)Y(x)$$

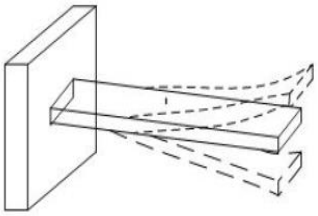

Fig 3 A cantilever beam under free vibration

Table 1 Typical conditions of beam

Beam configuration	$(\beta I)^2$	$(\beta I)^2$	$(\beta I)^2$
Fixed-Free	3.52	22.0	61.7
Hinged-Hinged	9.87	39.5	88.9
Fixed-Fixed	22.4	61.7	121.0
Free-Free	22.4	61.7	121.0
Fixed-Hinged	15.4	50.0	104.0
Hinged-Free	15.4	50.0	104.0

V. MODAL ANALYSIS

In order to predict natural frequencies and mode shapes of beam modal analysis is carried out using ANSYS WORKBENCH software. The beam is modeled with CATIA V5 software and then imported to ANSYS .The three dimensional beam model with fixed support is modeled as following conditions
Dimension and properties of the beam material are,
Length of beam = 306mm,
Thickness of beam = 5mm,
Width of beam=38mm,
Density of material = 2700Kg/m^3,
Modulus of elasticity = 70Gpa,
Material = Aluminium

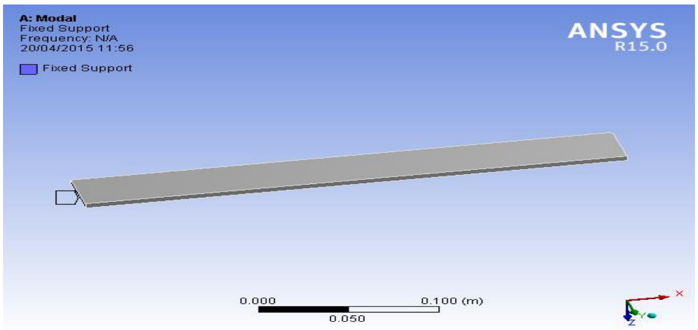

Fig.4.FEA model of beam

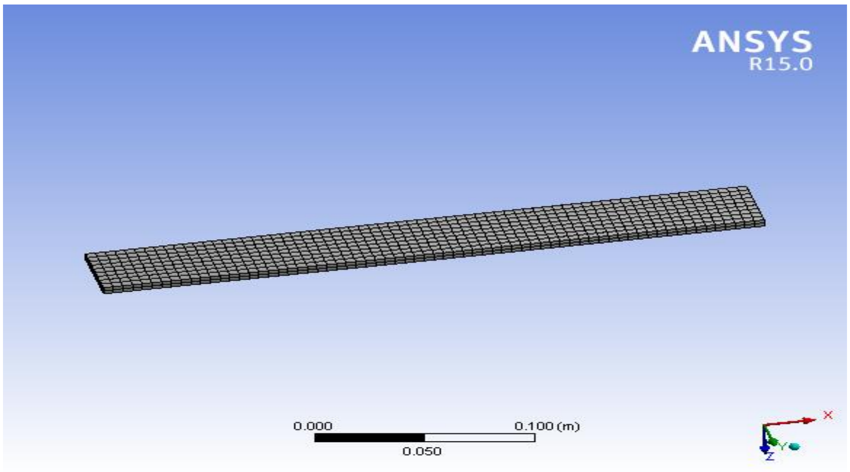

Fig. 5 FEA mesh model of beam

After meshing the modal analysis is done for next 4 mode shapes with resultant frequencies as following table
Table 2 First three natural frequencies of cantilever beam by ANSYS

Sr. No.	1 Mode	2 Mode	3 Mode	4 Mode
Frequency (Hz)	43.86	274.5	767.85	1510

VI. MATHEMATICAL ANALYSIS OF SECONDARY SYSTEM

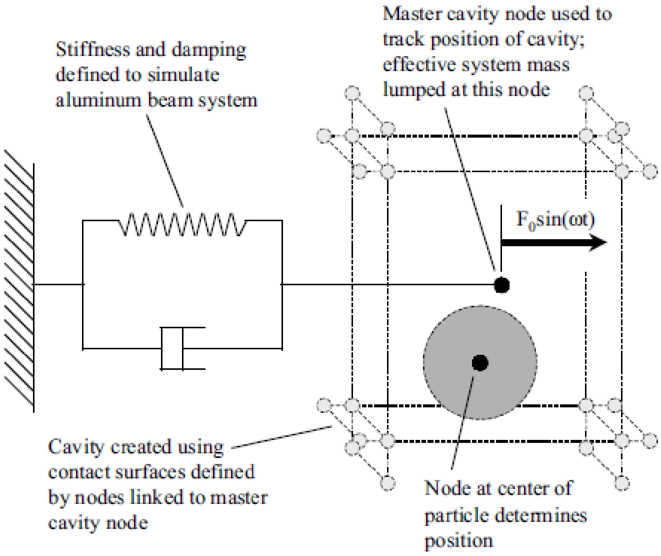

Fig.6D model used to design impact and particle dampers

As above stated the equation of motion for particle damping in horizontal beam structure is given by

$$M\ddot{x}+C\dot{x}+Kx=C\dot{u}+Ku+F, \qquad u= a \sin \omega t,$$

In modeling the magnitude of contact force F is not calculated in our project but its consideration and methods for calculating contact force are shown in last . The equation is solved up to certain limit and amplitude X is calculated for the base excitation .The secondary system consist of damper attached to the primary system i.e. cantilevered aluminium beam and this cavity with particles inside is rigidly fixed to beam.

VII. EXPERIMENTAL SET UP

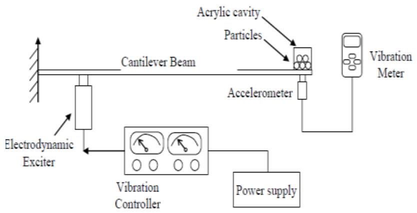

Fig.7Schematic of experimental setup

In order to study the damping effectiveness of particle damper an aluminium beam of rectangular cross section is selected. The schematic of experimental setup is shown in Fig7.1.The experiments are carried out on cantilever beam, having dimensions 306 mm length, 38 mm width and 5 mm thickness. The beam is rigidly fixed at the root and have first flexure mode at 44 Hz. The beam is excited near the root by an electro dynamic exciter. The testing is performed with excitation signals corresponding to 1.5 amp current. The excitation signal is held constant throughout experimentation. The response (displacement) is measured by miniature accelerometer attached at free end of beam. Testing is performed in undamped condition; beam with added mass and on beam with particle dampers containing different size of steel spheres and lead particles

Table 3Particle damper parameters

Material	Approximate diameter of particles (mm)	No. of particles
Steel	6.35	1
	3.97	4
Lead	1.72	35

VIII. RESULTS ANALYSIS

Effectiveness of particle damper is tested on cantilever beam with the help of different particles used in damper cavity damper. Amplitude of beam is measured without and with damper cavities by changing frequency and particles noted in table 4

Table 8.1 Response of beam with and without dampers

Frequency	Displacement of beam(micron)			
	Without damper	One steel ball	Four steel ball	Lead ball
30	204	127	137	147
32	215	136	151	156
34	241	155	152	169
36	269	173	174	180
38	300	201	204	192
40	371	226	232	242
42	420	266	263	255
44	454	329	296	282
46	433	301	278	276
48	427	279	252	220
50	345	233	202	191
52	280	204	183	175
54	228	175	143	159
56	192	140	122	138
58	175	124	110	118

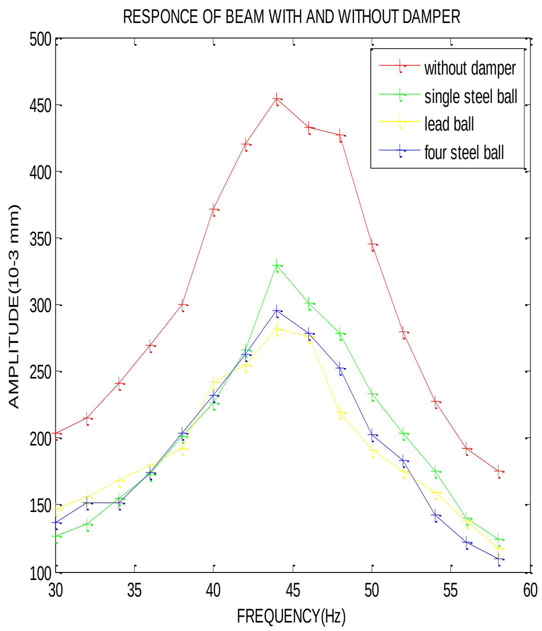

Fig 8 Response curve for with and without dampers

Effectiveness of particle damper is tested on cantilever beam with the help of different particles used in damper cavity damper across the length of beam. Amplitude of beam is measured with damper cavities by keeping frequency constant at resonance condition noted in table 5

Table5 Response of beam displacement with dampers across the length

Distance (mm)	Displacement of beam(micron)		
	Single steel ball	Four steel balls	Lead particles
55	437	450	430
75	398	438	425
95	373	398	419
115	337	360	414
135	312	353	409

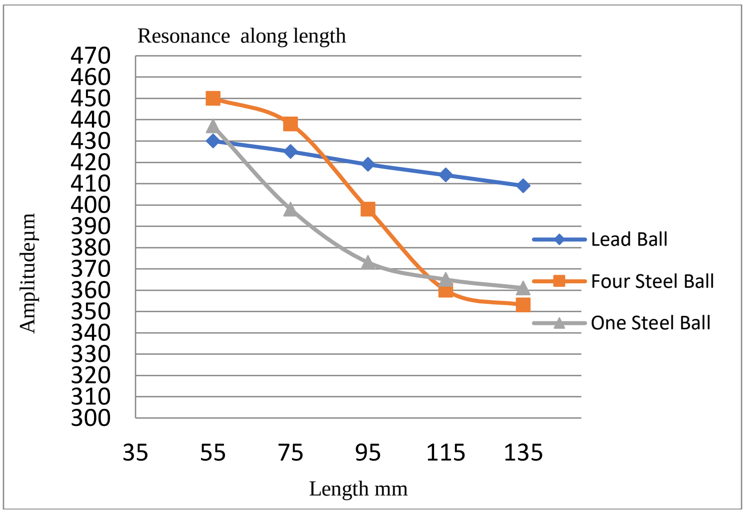

Fig 9 Response of beam displacement with dampers across the length

IX. CONCLUSION

The characteristics of three distinct configurations of particle impact dampers have been experimentally investigated beginning with a single particle and progressing to multiple layers of particles. From experimental analysis it is concluded that:

- Damping effectiveness depends on type of material of particles used.
- Particles of material having high density (i.e. lead) shows more damping effectiveness compared to low density (i.e. steel).
- The damping effectiveness depends on mass of particles, as mass increases damping effectiveness increases at certain level.
- Thus damping effectiveness is optimum for certain mass ratio which is the ratio of mass of particles to mass of beam.

Effectiveness of particle damper is checked on cantilever beam. It is found that designed damper is very effective to reduce vibrations of beam when it is analysed for various excitation frequencies nearer to natural frequency of cantilever beam.

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