

# **Review on Particle Damping Technique for Vibration Suppression**

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**ABSTRACT:** Particle damping is a technique of providing damping with granular particles. The particles absorb kinetic energy through particle-to-wall and particle-to-particle frictional collisions. Because of its extreme simplicity, high effectiveness and low cost, it has a tremendous potential for vibration and noise suppression in a broad range of application. Therefore, they are suited for applications where there is a need for long service in harsh environments. Applications of particle damping founds in weightless environments of outer space, in aircraft structures, to attenuate vibrations of civil structures, in tennis rackets etc. as well as can be used where either inherent cavity is present or there is a scope to create it. Paper is a review of various literatures available on vibration suppression by particle damping technique. The literature review reveals that the importance of particle damping technique in vibration suppression

**KEYWORDS:** Suppression, Particle Damping, Collision, Attenuate.

## **I.INTRODUCTION**

Damping is an influence within or upon an oscillatory system that has the effect of reducing, restricting or preventing its oscillations 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. Viscous and viscoelastic damping usually have a relatively strong dependence on temperature. Friction dampers, while applicable over wide temperature ranges, may degrade with wear. 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.

## **II.VIBRATION CONTROL TECHNIQUES**

There are different methods to control vibration and can be divided into three main categories, namely, passive, active, and hybrid vibration control illustrated in Fig. 1. Active and passive damping techniques are common methods of attenuating the resonant vibrations. Passive vibration control systems function without external assistance, e.g., they do not require a power source, simply because they are driven by the vibration itself. In most cases, they offer the simplest and cheapest solution to the problem. They require little or no maintenance, and installation is relatively simple. The typical example is a tuned mass damper, which consists of a mass-spring-damper system, is a common example for vibration absorbers that operate on the same principle. Contrary to passive systems, active vibration control systems depend on a power source. They require power for operating the sensors that sense the level of vibration, the control systems that process the sensor signals and send driving signals, and the driving devices that apply forces to reduce the level of vibration. Active vibration control systems are mostly more complex and expensive than passive

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systems, require maintenance, and there is a higher possibility of failure. Hybrid control systems utilize both passive and active components

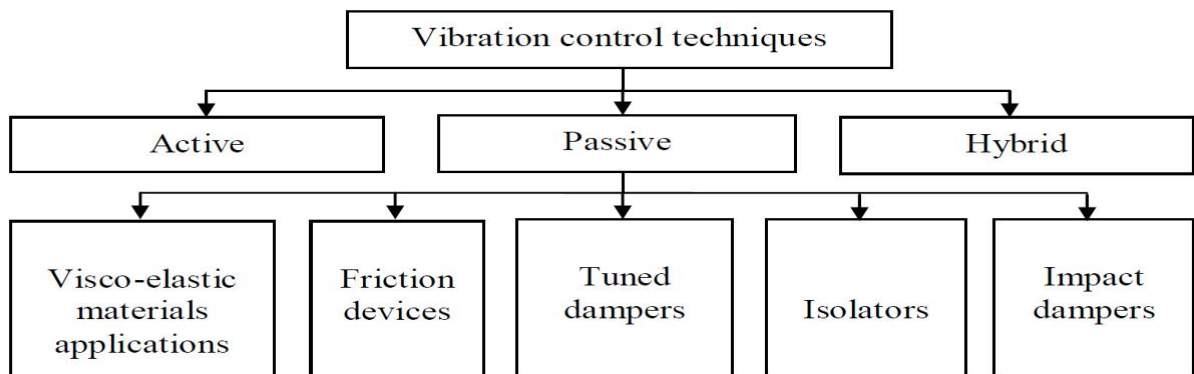


Fig. 1. Vibration control techniques

There are several passive damping techniques as illustrated in Fig. 1. such as viscoelastic materials applications, friction devices, tuned dampers, isolators, impact dampers. However, performance of all virtually existing damping methods depends on operating temperature. Viscoelastic materials have long been used for increasing damping in structures. However, they lose their effectiveness in low and high temperature environments and degrade over time. Hence there is a need of damping mechanism which can operate in harsh environment for a long period of time. Particle impact damping offers the potential for the design of an extremely robust passive damping technique with minimal impact on the strength, stiffness and weight of a structure. With a proper choice of particle materials (for example, lead, steel, or tungsten carbide), this technique is essentially independent of temperature and is very durable. Also, this technique is advantageous over single-particle impact dampers that suffer from impact-induced high noise levels and surface degradations as well as high sensitivity to container size and input excitation.

### III. PARTICLE DAMPER WORKING

Particle dampers, also known as shot dampers or granular-fill dampers are passive damping devices. The principle behind particle damping is the removal of vibratory energy through losses that occur during impact of granular particles which move freely within the boundaries of a cavity attached to a primary system. Particle damping with suitable materials can be performed in a wider temperature range than most other forms of passive damping. Therefore, it can be applied in extreme temperature environments, where most conventional dampers would fail. The damping efficiency of particle damping depends on cavity dimensions. When the optimum dimensions of the cavity are large, the optimum cavity may not be attached from practical design point of view. In such a case, the damper performance is retained when particle dampers are replaced by multi-unit dampers with a moderate number of small cavities. Particle damping technology is a derivative of impact damping with several advantages. As shown in the idealized single-degree-of-freedom system in Fig. 2, 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.

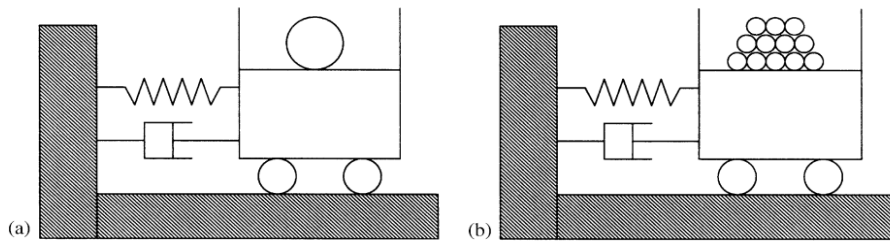


Figure 2: Idealized single-degree-of-freedom system with (a) impact damper and (b) particle damper.

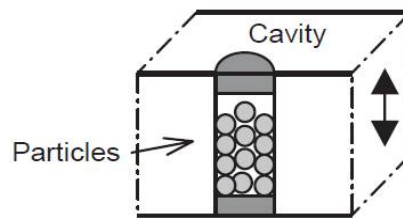


Figure 3: Schematic of a particle damper.

Studies conducted over recent years have demonstrated the effectiveness and potential application of particle dampers to reduce vibration for various applications.

#### IV. MATHEMATICAL MODELLING

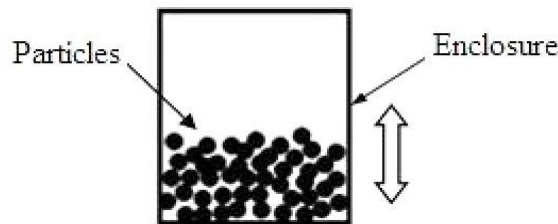


Figure 4: Schematic of Particle Damper

Specific damping capacity,  $\Psi$ , is defined as the kinetic energy converted into heat per cycle ( $\Delta T$ ) normalized with respect to the maximum kinetic energy of the structure per cycle ( $T$ ), i.e.

$$\Psi = \frac{\Delta T}{T} \tag{1}$$

A cycle is defined as the duration between two successive peaks in the velocity of the primary mass,  $V$ . Then,  $T$  is maximum at the start of a cycle and is given by

$$T = \frac{1}{2} MV^2 \tag{2}$$

The energy dissipated during the  $i$ th cycle is calculated using

$$\Delta T_i = T_i - T_{i+1} \tag{3}$$

In reality, there are times during a cycle when particles move separately from the enclosure, and some other times they move in contact with the enclosure. Since our method of experiment cannot determine whether or not the particles in contact with the enclosure at any given instant, we assume that the particles are always in contact with the enclosure

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at velocity peaks. Then, the primary mass,  $M$ , includes the mass of the particles,  $m$ , and the energy dissipated can be expressed as;

$$\Delta T_i = \frac{1}{2} M (V_i^2 - V_{i+1}^2) \quad (4)$$

Substituting equations (4) and (2) into equation (1), we express damping during the  $i$ th cycle as;

$$\Psi_i = \frac{V_i^2 - V_{i+1}^2}{V_i^2} \quad (5)$$

Friend and Kinra introduced a parameter  $R$  (effective coefficient of restitution) that will give the measure of how much energy dissipation occurs due to inelastic collisions and frictional sliding amongst the particles, and between the particles and the enclosure walls. Defining  $v_p^-(v_p^+)$  and  $v_2^-(v_2^+)$  be respectively the velocities of the particle and the primary mass before (after) the impact, they defined  $R$  as

$$R = \frac{(v_p^+ - v_2^+)}{(v_p^- - v_2^-)} \quad 0 \leq R \leq 1 \quad (6)$$

then, the energy dissipated during an impact may be expressed as

$$\Delta T = \frac{1}{2} (1 - R^2) \frac{m}{1 + \mu} (v_p^- - v_2^-)^2 \quad (7)$$

where  $\mu$  is the mass ratio of the particles with respect to the primary mass,  $m/M$ .  $R$  is estimated by minimizing the difference between theory and experiment using least square method.

There are several parameters that affect energy dissipation during an impact, i.e.

$$\Delta T = f(m, d, g, M, \omega, U, R), \quad (8)$$

where  $g$  is the gravitational constant,  $\omega$  is the fundamental frequency (radians/second),  $d$  is the clearance, which is the distance between the top of the bed of particles at rest and the ceiling of the enclosure, and  $U$  is the amplitude. The semicolon separating  $R$  is used to emphasize that  $R$  is obtained by curve fitting experimental data to the model. In dimensionless parameters, the damping can be seen as:

$$\Psi = f(\mu, \Delta, \Gamma, R), \quad (9)$$

where

$$\Delta = \frac{d\omega^2}{g} = \text{dimensionless clearance, and}$$

$$\Gamma = \frac{U\omega^2}{g} = \text{dimensionless acceleration amplitude, in units of } g.$$

In this study, dimensionless parameters will be extensively used to present all experimental results.

## V. LITERATURE REVIEW

M. Senthilkumar, et. al. [1] in this paper The main focus of this investigation is on a damping enhancement method with particulate materials. A boring bar is treated with longitudinal holes embedded with metal particles. The experimental investigations on the effectiveness of particle damping in vibration control of boring bar are carried out and reported. The particle damping is found to be more effective. Although it is nonlinear, a strong rate of energy dissipation is achieved within a broadband range. It was found that considerable reduction in vibration was achieved with the particle damping. Results from testing different types of particles indicated that the frequency at which maximum damping occurs and the amount of damping obtained depend on properties of the particles. This suggests that the particles can be designed to target vibration reduction in a specific frequency range

Zhiwei Xu, et. al. [2] The purpose of this paper is to report an application of particle damping technique for noise reduction of a desk-top industrial machine. Particle damping is a technique of providing damping with granular particles embedded within small holes in a vibrating structure. In a recent development, they applied the particle damping technique to desk-top banknotes processing machine as a task to substantially reduce its noise (by 6 dB(A)) to the level of a standard requirement when it is in operation in an office environment. The objective of this paper is to bring attention of the particle damping technique to the academic and industrial communities to further stimulate

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development in its fundamental investigations and broad applications in many more fields for vibration and noise reduction.

Richard Ehrgott, et. al. [3] in that work High power turbopumps are frequently used to supply propellants to the combustion chambers of rocket engines. Due to the high pressures and flow rates required, turbopump components are subjected to harsh environments which include dynamic excitation due to random, sine, and acoustic vibration. Additionally, fluid-induced forces can couple with the dynamics of the structure resulting in flow induced instabilities (flutter). Structural response to these forms of excitation results in reduced fatigue life and increases the likelihood of an operational failure. Particle damping has been used successfully on vibration problems in the past by increasing the damping and therefore reducing the response to acceptable levels. Empirical methods have typically been employed to evaluate the performance of the particles in reducing the structural response. This work explores the use of finite element methods to estimate the effectiveness of particle damping in a typical non-rotating turbo pump component. Ax symmetric harmonic models are used to estimate the increase in modal damping produced by the addition of particles in the cavity of an axisymmetric seal. Target modes of vibration are evaluated to quantify how particle damping contributes to the total modal damping and how the total modal damping is altered by geometry changes in the seal design.

Jianglong Fang, et. al. [4] In this paper, the study is carried on a piece of stainless steel panel. Variable density method based topology optimization is used to arrange the stiffeners. Via finite element method, the sound insulation properties of the panel and the stiffened panel are calculated. To improve the sound insulation of the stiffened panel, small tungsten particles were filled into the ribs 'cavities. Through simulative and experimental methods, the roles played by stiffeners and non-obstructive particle damping (NOPD) in improving the sound insulation of the panel were analyzed. Then the stiffeners on the panel were removed and a structure filled with small particles was attached to the proper place of the panel. The sound insulation of the panel attach with NOPD was tested in a semi-anechoic chamber. The result showed that NOPD can not only improve the sound insulation of panel but also add much less additional mass and don't change the original structure compared with arranging stiffeners. The result of this paper may be instructive to the improvement of the sound insulation of a thin panel.

Pranali Khatake et al. [5] introduced a vibration attenuation technique for boring bar through the implementation of passive damper. They used damping particles within the boring bar and experimental investigation was undertaken to observe the surface finish of specimen using different overhang lengths of boring bar during operation. The results proved that the chatter of the tool is suppressed at a larger amount which means the self-excited vibrations of the boring tool are reduced.

Steven E. Olson et al. [6] established An analytical particle damping model. They did an analytical evaluation of the particle damper. They utilized the particle dynamics method based on the kinematics of particle damping, involving shear friction between the particles and contacting areas and the dissipation of energy in the form of heat of the particle material. Interaction forces between the individual particles and the cavity walls are calculated based on force-displacement relations. Application of the model has been demonstrated by simulating laboratory testing of a cantilevered beam.

## VI. CONCLUSION

This review paper reveals that passive damping techniques by using damping particles like steel, plastic granules, etc. can suppress the vibrations during to the desired amount and also achieve target of human comfort. Particle damping is a better passive damping technique which can retain its stiffness within permissible limits. This proves to be a simpler and effective method of vibration reduction. This can be used over a wide range of temperatures and frequencies and shows a wide scope of applications. This has investigated the damping enhancement method with particulate materials like damping particles. This suggests that the Particles can be designed to achieve mitigation of vibration. The review shows a greater damping capability in that particle damping.

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