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A REVIEW ON PERFORMANCE OF PARTICLE DAMPER METHOD TO SUPPRESS THE VIBRATIONS FOR DIFFERENT APPLICATIONS

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ABSTRACT

Noise and vibration two are major parameter of industrial application. Vibration damping is reactive vibration control method, which is mostly used to control and diminish surplus vibrations in mechanical system. In particle damping (PD), an impact mass is tightly attached to the main vibrating configuration to satisfy the vibrations. The impact mass either contains single particle or number of particles. The dissipation of vibrational energy will occur due to impact, exchange of energy and friction in between main mass and impact mass. Particle impact dampers are used to decrease the undesirable vibration in engineering applications. This paper presents a review on particle damping method applied for different applications to suppress the vibration. Impact damping technology has been developed and widely used for different applications such as robots, spacecraft, airplane, rocket launcher, surgical and dental application, and other lightly damped structures to damp the vibrations.

Keywords: *Vibration, suppression method, damping, particle damping.*

I. INTRODUCTION

Vibrations occurs when the system or body displace from its equilibrium position. The system retrieves to return its initial equilibrium position under the restoring forces (such as elastic forces, gravitational forces, for a simple mass is attached to a spring, for a pendulum). The system tends to keep back to its original position of equilibrium. The system is the combination of the elements. They act together to accomplish the objective. Most vibrations are unwanted in the machines and the structures. These vibrations produces increased stresses, energy losses, causes wear, increases in the bearing load, increases in the fatigue, create unwanted vibrations in the vehicle to create discomfort to passengers, also absorb the energy from the system. When the parts in the rotating machines rotates so there is need to balance to reduce the vibrations.

Vibration and Damping

Vibrations are one of the main reasons leading to partial damage and in some cases collapse of tall structures and the main cause of inaccurate operation performance in mechanical devices. One of the most common passive vibration control devices is called the Impact Damper. The impact damper is very common in industry due to its simplicity, low cost, robustness, effectiveness in vibration attenuation over a wide range of frequencies and accelerations. In particular, passive control methods are favoured because of their mechanical simplicity and lack of power requirement. Damping treatments are used for noise reduction, fatigue reduction, vibration isolation, and absorption of impact energies. Damping of structural vibrations can be realized through either active or passive means, the latter being the most common. Active damping techniques are not applicable under all circumstances due to power requirements, cost, environment, etc. Under such circumstances, passive damping techniques are a viable alternative. The primary property that a material must possess to become a good damper is viscoelasticity. It is a property in materials where the materials exhibit elastic and viscous characteristics when they are undergoing deformation.

This kind of impact causes an exchange of momentum between the main mass and the impact mass which results in very high damping. It can provide effective damping over a range of accelerations and frequencies in harsh environments where traditional approaches fail. Impact dampers have also been considered for use in harsh environments such as turbo machinery blade, since their effectiveness is independent of the environment. Impact damping technology has been developed and widely used for decades in manufacture of machine tool, robot, turbo machine, airplane, rocket launcher, and so forth. 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.

Development of Particle Dampers

The concept of particle damping could be traced back to 1937, when Paget was studying the vibration attenuation problem of the turbine blades, during which he invented the impact damper. The impact damper only involves a single particle, resulting in high noise levels and significant impact forces during the impact process, and it tends to become sensitive to the change in certain parameters (such as the excitation amplitude and the restitution coefficient).

Later on, in 1945, Lieber and Jensen proposed the concept of using a mass moving between two walls of a container to eliminate the vibration of mechanical systems, which evolved to the form of the impact damper. Because of a variety of flaws in a single-particle impact damper, its further application and development in more fields are limited. Hence, subsequent researchers have replaced the single particle with many smaller particles of equivalent total mass, thus resulting in the particle damper.

Particle damping is a derivative of single-mass impact damper that has been thoroughly studied on the influence of mass ratio, particle size, particle/slot clearance, excitation levels, and direction of excitation [1,2]. In the single-mass case, direct analyses exist and reveal design criterion for optimal efficiency based on reduction in system response. It is observed that a plastic ‘‘bean bag’’ filled with lead shot exhibited much greater damping effectiveness and ‘‘softer’’ impacts than a single lead slug of equal mass [1,3].

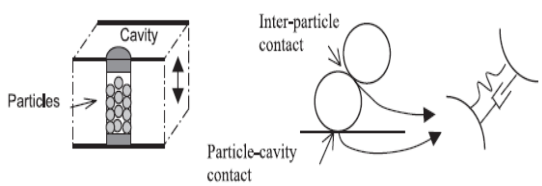

Figure 1 Particle vibration damper and its body contacts

Particle damping technology is a new one of passive vibration control. It is based on damping dissipation energy theory [1]. It provides damping effect through inelastic collision and friction of the particulate matter filling in the structure cavity, which restrains the structure vibration [2,14]. There is also momentum exchange mechanism, where momentum is transferred from primary structure into the particles to energy storage in terms of kinetic and strain energy [3].This technology has many advantages such as good performance of vibration suppression and high temperature resistance [4].

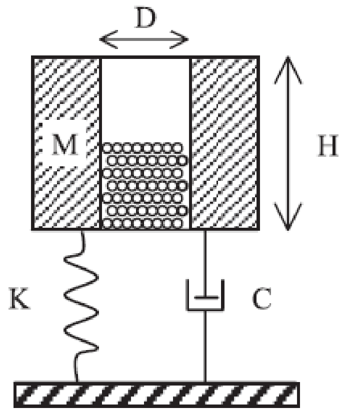

Figure 2 Single Degree of freedom Particle vibration damper

Fig shows the physical system of a simple particle vibration damper. It consists of a structural body with a vertical hole partially filled with metal particles of small size. The structural body is modeled as a single degree of freedom (SDOF) system with mass M, stiffness K, and damping coefficient C. The hole has diameter of D and a depth of H.

Metal or ceramic particles or powders of small size are directly placed inside the containing holes with the holes partially or wholly filled. The size of the particles is typically less than 1/5 of the hole size in diameter and is usually in the range 0.05–1 mm in diameter. Thus, it is not uncommon that a single hole may contain a large number of particles in an order of 1000 or even 10 000. Metal particles of high density usually the best choice. Within this size range, the particles are considered non-cohesive [4-5]. The important parameter of particle contained in cavity is internal coefficient of friction. It is depends on the material type and size [6]

Figure 3 Particle Damping Material

On the basis of the traditional particle dampers, several variants have evolved. Each variant has its own features so that it can be selected depending on the engineering requirements. According to the different aspects of the improvements made in the traditional particle dampers, these variants can be classified into three main categories (1) the configuration improved type, (2) the material improved type, and (3) the combination type.

II. METHOD & MATERIAL

There are two methods of damping in general, Passive damping and Active damping.

Passive damping:

It is method that uses the inherent property of the material used to provide energy dissipation and energy absorption. Materials that exhibit such properties are known as visco-elastic materials. The materials that exhibit both viscous and elastic property when subjected to a force is known as visco-elastic material.

Active damping:
It is the method that uses sensors and actuators to induce a energy absorbing activity using pizeo-electric dampers to actuate the energy absorption process. The pizeo-electric dampers provide electric signals that actuate the damping property in the material. Such technology is used to actively reduce vibrations, often applied in professional sports.
In this study we will be briefly discussing on Passive methods of damping as it is easy to implement and is cost effective materials used for damping.

Material

A. Rubber:
Rubber is the most common material that is used for vibration damping. It is obtained from natural sources, and found its way into grippers and hand held items perceived to provide comfort long before vibrations and its reduction was better understood. It is a polymer that has the best visco-elastic property. Polypropylene\ butyl rubber blend polymers, which are extensively used in damping tennis bats and cricket bats are made out of rubber [2].

B. Metals and alloys:
Certain alloys called as shape memory alloys, and ferromagnetic alloys are used as vibration dampers. Ferromagnetic alloys provide damping by magneto-mechanical mechanism (movement of magnetic domain along the phase boundaries). Shape memory effect refers to the ability of the material to transform to a phase having twinned microstructure that, after subsequent plastic deformation, can return the metal to its initial phase.

C. Polymer materials:
Due to the viscoelastic behavior exhibited by certain polymer compounds, it finds large applications in damping sports equipment. Rubber although being a good damping material itself, has low stiffness and modulus of elasticity values. To compensate this and to enhance the performance limitations of the equipment polymers are blended with natural rubber. Polymers that are used in vibration damping include polytetra floroehtylene (ptfe), polypropylene/butyl rubber blend, urethane interpenetrating polymer blend.

D. Composite materials:
Certain fibrous structural composites are used for vibration damping. Due to the interpenetrating mesh of fibers that create a hollow spacing even in between the resin matrix provides the damping mechanism. Also with the rise in temperature (eg.50oc) interlayer of the composite degrades and stiffness of the matrix reduces significantly.

III. APPLICATION

Literature review
Zhiwei Xu*et al.* (2005) studied that particle impact damping reduce the vibration. Experiment were perform on elastic cantilever beam. On beam, holes are provided with equal diameter and distance and filled with the particles. Their main purpose is to reduce the vibrations by shear friction produced by shear gradient with the lengthwise to the structure. They develop an experiment model to calculate the shear forces between the particle to particle and the particles to wall. Also they present a numerical procedure to calculate the damping effect of vibrating structure. They conduct the experimental test on the beam and plate to calculate the various damping treatments. The presented model results are validated with the experimental results. The particle impact damping is found effectively robust for a broadband range. [7]

***Simonian, S. S., Pillsbury* et al. (2002)** studied that Particle damper designs were also successfully applied to suppress steering wheel vibrations during idling, and to suppress noise and vibration of electric motors used in steering control systems in the automotive industry. A steering wheel particle damper is designed to replace a much more expensive elastomeric tuned mass damper. The motor particle damper is specially designed to suppress a high frequency torsional vibration mode of the motor that is responsible for generating an annoying noise level. This particular damper design for the motor is composed of an annular circular cavity with internal pie-shaped radial partition walls to make the damper effective during torsional oscillations of the motor spigot to which it is mounted.

As can be seen from these initial test results, the particle dampers are quite effective in reducing vibration amplitudes. A patent has been applied and is pending for the above mentioned applications.[8]

M. Senthilkumar,et. al.(2011) 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. [9]

Liming song, Wangqiang Xiao, Et al, (2018) Vibration in the mining dump truck is an important evolution. Particle damping technology was successfully used to control the vibration of mining dumb truck cab. Overall study conclude that, based on particle damping technology the mining dumb truck cab vibration control by theoretical simulation with actual testing. The vibration effect result was observed by actual test results. [10]

S. Devaraj*et al*. (2014) studied to improve the surface quality of the workpiece using particle damping method in the boring bar.Damping to put down by force the vibrations was provided by drive in the fine particles inside small hole of a vibrating assembly. They accomplished experimental analysis for the surface roughness measurement of work pieces by using these four materials Copper, Aluminum, Zinc and Silicon particles with having different densities. After this experimentation they get results that proved that the use of silicon and zinc particles shows a smaller amount damping ability but when compared to the damping abilities of the boring tool using Copper and Aluminum particles and thus it discovered that the surface finish value of the work piece can be enhanced using particle impact damping. [11]

Yang Yiqing et al. (2015) evaluated that during milling operations, the chatter vibration creates poor surface finish, tool wearing and decreases tool efficiency. For high speed cutting process, long slender end mills are essential for milling of aerospace product. The end mill along with passive damper is designed and performance of damping tool had evaluated. It is observed that the long slender end mill embedded with passive damper enhances machining stability. [12]

Zhaowang Xia, Yuanyuan Fang, Particle damper can be applied in extreme temperature environments. His performance of particle damper is highly nonlinear whose energy dissipation is derived from a combination of mechanisms including plastic collisions, friction, and momentum transfer between particles. Overall study conclude that, simulation and the experiment results indicates that the damping performance depends on the relationship of the mass fill ratio and particle densities and the maximum value of the primary plate amplitude increases as the particle density increases and in the same particle densities, the maximum value of the primary plate amplitude is always smaller for the mass fill ratio of 70% than for the mass fill ratios of 50% and 30%. [13]

Michael Heckel*et al.* (2012) investigated in the surgical and dental applications.Instrument is constructed on the oscillatory mechanism provide unwanted vibrations to the operator's hand while he working with the instruments. Based on previous researches on optimization of fine particles create a model of granular damper that damper can be reduces the vibrations of oscillatory saw by two time's solid mass. He concluded that the granular dampers dissipate the vibrations more efficiently than solid mass. [14]

K.W. Chan et al.(2005) applied on electronics manufacturing equipment. Particle enclosure were designed for a bond arm.it is light and stiff and consisting of a shell structure and with 1.5 mm thickness moving at high speed. Particle damping would be a promising techniques for attenuating the residue vibration of the bond arm during positioning.[15]

Jo et al. (1989) used a multiunit IVA, in multiple cavities, for reducing vortex-induced vibrations of highway light poles. It was demonstrated that the amplitude of vibration, for the first out-of-plane oscillation, could be reduced up to 90%.[16]

Zhaowang Xia et al,(2011) feasibility study on vehicle drum break using particle damping to control the noise and vibration. Using DEM and FEM to calculate and design particle damper. This method also investigate the properties of particle damper in rotating structure. The effect of particle damping is successfully examined. [17]

IV. CONCLUSION

This survey paper presents an overview of particle damping technology and its application.Many researches have carried out various theoretical, numerical, and experimental studies on particle damping in the recent decades. Particle damping is a better passive damping which can retain its stiffness within permissible limits. Particle damping can be used over a wide range of temperatures and frequencies and shows a wide scope of applications. From literature it conclude that particle damping technology has been widely used in the aerospace, mechanical, and electrical fields.

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