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Review Article

A Review on Design and Validation of Performance of Particle Impact Damper

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Abstract

The vibration generates difficulties to the structure which reduces the structure life and increases the possibilities of failure to the structural. This paper presents a review on research carried out on behaviour of various parameters of particle impact damping. The methods like experimentation, analytical and discrete element method to validate results were used. Actual modelling of the experiment is done and using vibration exciter vibrations are given and readings are recorded by FFT analyser. Researchers have used the parameters like packing ratio, material of beam, material of fine particles and its size. Some researchers have focussed on the design methodology of the particle damping. While experimentation beam is studied with particles and without particles. The particles were used like copper, aluminium, glass, sand, lead, tungsten carbides. The material of the beam is used as aluminium and steel so that the experimentation is carried out on the beam. It is found that the particle impact damping is most effective for vibration suppression. The damping performance of particle impact damper has been found highly nonlinear behaviour. This paper focuses or discusses on the methods to reduce vibrations by using particle impact dampers.

Keywords: *Damping, Impact, Friction, Vibration.*

1. Introduction

Vibration means the displacements of the particle, body or any system of connected no of parts moves from the position of equilibrium. 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.

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. For example an automobile is the system which is the combination of the elements (wheels, car body, suspension, and so forth) work together. The output of the static element whose is the given time only depends only on the input at the while the dynamic element is one whose output depends on the past dynamic. In this way we speak the static and dynamic systems (S. S. Rao 2011). In static system which contains all the elements. In the dynamic system which contains at least one dynamic elements.

Elementary parts of the Vibrating structure

In general the vibrating system consist of the spring (is used for storage of potential energy), a mass or inertia (is used for storage of kinetic energy), and damper (is used for loss of energy).

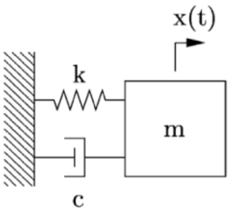

Fig.1.1.1 Elementary parts of vibrating system (Dr. V.P. Singh 2014)

In the undamped vibrating system the potential energy is transfer to kinetic energy and kinetic energy transfer to potential energy vice versa. In the damped vibrating structure the energy is scatter in the each cycle of vibration and should be replaced by external source. If there is steady state vibration is to be present.

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Vibration and damping

The mechanical devices and structures are fails due to excess stress and strain are the major causes. When the vibration excitation frequency matches to the resonance frequency it creates the resonance it creates the catastrophic failure because the vibration frequency is very large. The one of the most famous example is the failure of Tacoma Narrows Bridge, in 1940. Beam goes under twisted vibrations due to aerodynamic Move back and forth very rapidly.

While designing of the machinery and the structures the attention is given on to reduction of vibration to reduce noise, increase fatigue life, and reduce catastrophic failure. This is firstly achieved by reducing the source of vibrations through the system and the dynamic balancing of the rotating parts.

The dampings are such as active, semi active or passive. When the energy is removed from the system through feedback system in control system is known as active damping (S. S. Rao 2011). The exerting of counter force or moment in a controlled manner by which we can achieve active damping. For example a layer of piezoelectric that can apply a bending moment on a structure when the electric current is applied to it.

In semi active system the passively generated damping system controlled according to parameter tuning strategy with a small amount of effort. For example in the semi active suspension in the recent vehicles uses viscous fluid damping with adjustable orifices dampers packed with magneto rheological viscous fluids it changes its viscosity when exposed to the magnetic field. The damping is changes according to the road conditions. There are fully advance vehicle suspensions that can observe the road conditions as well as vehicle motion and change the damping according to conditions.

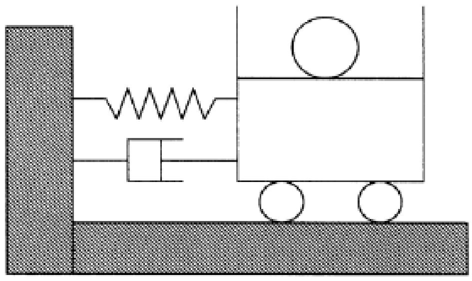
There are many different techniques to scatter the energy of vibrating structure uses in the passive or uncontrolled dampers. The wide classifications of viscoelastic materials applications, friction devices, particle and tuned mass dampers, viscous fluid dampers, and isolators.

Brief overview of particle dampers

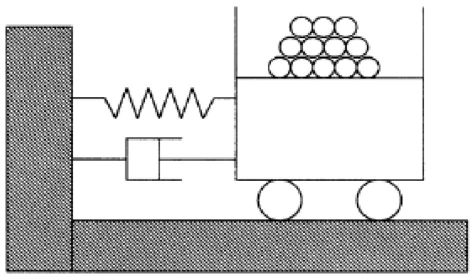
Particle dampers (PDs) are those the container or enclosure filled with one or more particles (metal, ceramics, glass, etc.). The particle impact damping works on by dissipating energy through inelastic and friction between the particles as same and as well as the wall of the enclosure. The particle dampings are simple and easy also low cost so the PDs have wide range of applications. Figure shows the types of particle impact damper, tuned mass dampers and impact damper. The figure shows the damper, spring and box which is represent the vibrating assembly and the inside box content represent the type of the damper. (Cyril M. Harris *et al*2002)

The main advantage of the particle impact damper is they can work over extreme conditions means over 600^0 C temperature conditions and extensive range of frequencies. The researchers have proven that by experimentally particle impact damping is very effective even when the ratio of the mass of all particles to the system mass is very small.

The disadvantages of the particle impact dmaping are mostly high amplitude or acceleration. The damping devices show that the horizontal vibration PDs are not operative below the $0.3\ _{go}$ acceleration level for the reason that of static friction. Designed for the assignment of particle impact dampers on an assembly, the points of primary acceleration are recognized through a finite element method (FEM) analysis or by means of acceleration measurements. A damper is at that time a selection of for the measured parameters.



(a) Impact Damper



(b) Particle Damper

Fig 1.3.1 Schematics of types of particle impact dampers (Vikas L. Shinde *et al,* 2016)

2. Literature Review

Zhiwei Xu *et al*. (2005) studied that particle impact damping gives the vibration destruction. In their research work, coarse particles are inserted into their respective holes into vibration structure. In this research work they uses an elastic cantilever beam which is drilled through horizontally and these holes are filled with the particles. Their main focus is on to reduce the vibrations by shear friction produced by shear gradient with the lengthwise to the structure. They develop a physical model to calculate the shear forces between the particle layers and the impact of the particles on the inside of the hole. 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.

M. Saeki (2005) proposed that the multi-unit particle dampers are the passive damping devices, those include the fine particles containing holes in the primary structure. Their main principle behind the particle impact damping is to remove or to reduce the vibration energy through losses that happen when the particles are strike on the wall of the hole. They presents the experimental results and the analytical results of the horizontal vibratory system of multi-unit particle system. An analytical method solution is based on the discrete element method which is presented. They compares the experimental results and analytical results these results shows that the accurate approximations of rms response of a main structure can be achieved. The results are show that the response of main structure is depends on the number of enclosures and the dimensions of the enclosures.

Vikram K. Kinra *et al*. (2005) investigated that the particle impact damping (PID) is used for the cantilever beam. The particles are filled with enclosure attached to its free end of beam. The particle impact damping uses various materials for the damping of vibrations such as lead balls, steel balls, copper balls, glass balls, tungsten carbide pallets, lead dust, steel dust and sand. The main objective of the study is to collect the additional data for the particle impact damping (PID). In his study studied five materials such as tungsten carbide, steel, glass, lead and sand. In his study they studied the particle material, number of particle, effect of mass ratio and shape of the particles on the particle impact damping (PID). The experimentation was conducted and the experimentation results shows extra advanced model of PID should include the particle size and number of particles and release the restriction of the all particle moving as a one particle.

M.R. Duncan *et al*. (2005) found that the results from computer simulations are used to examine the damping performance of single particle vertical impact damper, used with varied range of excitation frequencies and amplitudes, also particle mass ratio with structure, enclosure cap clearance ratio, structural damping ratios, and coefficient of restitution. In this study they measure the damping performance, particle flying times and structure contact times are studied. They studied the performance of the both undamped natural frequency and off resonant conditions in complexity. They found that maximum damping is occurred at fixed oscillation frequency at an ideal height of lid increases with increases with mass ratio also increases in structural damping ratio and decrease with the coefficient of restitution.

Martin Sanchez *et al*. (2013) introduced that response of a single degree of freedom of mechanical system which is containing the primary mass M, a linear spring, a viscous damper and particle damper. In his study the particle damping lies in prismatic enclosure with adjustable height in which the particles are filled means total mass mp. He show that for small size enclosure the system does not respond the fully detuned mass limit in an uninteresting manner. Somewhat the system increases its effective mass up and above Mþmp before it reaches the predicted value. Furthermore he show that the same effect seems in tall enclosure where the system reaches to its limit effective masses below the expected value of M.

Yanchen Du *et al*. (2008) investigated the conventional impact damper (CID) for the energy dissipation mechanism for generally momentum exchange and friction. While the impact process is running then the lot of energy cannot be removed but echoed with the vibrating structure. As well the conventional impact damper (CID) produces extra vibrations to the system or also increase the response in the low-frequency vibration. To overcome these inadequacies, they investigate proposes a new fine particle impact damper (FPID). After that the experimental work is carried out on the cantilever beam with conventional impact damper (CID) and the beam with the FPID respectively carried out. To calculate the performance of the FPID. After conducting the experimentation they found that the FPID has a better performance in the vibration damping compare to CID. They investigate that the FPID well work to control vibration with frequency lower than 50 Hz.

S. Devaraj *et al*. (2014) studied the fine particle impact damping method in boring bar operation for the surface quality improvement of the work piece. 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, Aluminium, 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 Aluminium particles and thus it discovered that the surface finish value of the work piece can be enhanced using particle impact damping.

Steven E. Olson *et al*. (2003) studied an analytical model of particle damping. They conduct an analytical calculation of the particle damper. They developed the particle dynamics method constructed on the kinematics of particle damping, containing the shear friction between the particles of the materials and contacting area with particles and the dissipation of energy in terms of heat of the particle material. Contact forces between the discrete particles and the enclosure walls are intended based on force displacement relations. Use of the model has been validated by simulating laboratory analysis of a cantilevered beam.

Bryce L. Fowler *et al*. (2000) represented that the current studies into the effectiveness and predictability of particle impact damping. Their exertions had focused on distinguishing and forecasting the performance of a wide range particle materials, shape and size in the library conditions, also at high temperature. Various procedures used to collect the data and extract the feature of the nonlinear damping phenomena are showed with interesting test results. The experimental results were **c**ompared with the analytical simulations accomplished through an explicit code, constructed on the particle dynamics method. This method can be developed for support to this work.

Michael Heckel *et al*. (2012) investigated that in the instrument, which are used in the surgical and dental applications those 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 he 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.

Conclusion

This review paper expresses that from above literature review, a lot of research has been done on particle impact damping, experimentally, numerically and analytically. The all the researchers had worked on the damping of vibration by using various methods such as particle impact damping, passive or uncontrolled dampers use many different techniques to dissipate the energy of a vibrating structure. The objectives of most of the work carried by various authors were to work on the cantilever beam to dissipate the vibration in the beam. From the study of the various methods they design a mathematical model to calculate the damping effect. Passive damping techniques completed with the damping materials particle such as copper balls, lead dust, silicon, rubber etc. can suppress the vibrations during the various operations and in the cantilever beam to the required amount. Particle impact damping is the most effective damping techniques to reduce the vibrations. This proves to be a simpler and effective method of vibration reduction. This method can be used in the extensive range of temperatures and low frequencies.

It is observed that various techniques are designed such as discrete element method (DEM) can be effectively used for the analysis.

The vibration between a tool and a work piece is a significant issue in machining operations. So the researchers work on boring bar. They use the method particle impact damping (PID) to reduce the vibration of the boring bar. The literature review is concerned with the studies on design, methodology, experimentation and validation of particle impact damping.

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