# PARTICLE DAMPING METHOD AND ITS APPLICATIONS

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***Abstract*—** The use of particles in the machine element suppress the vibration for particular application. The particle damping technology achieve high damping. It's absorb kinetic energy into heat energy by collision between particles to cavities and particles to particles. So it reduce both noise and vibration of the structure. This technology is mostly suitable for harsh environment. Number of particles are placed inside the cavity or attached to the vibration element to suppress the vibration. Stainless steel, aluminium, copper, tungsten carbide etc. types of material and sized used to suppress the vibration. Stainless steel and aluminium are used because of high damping for vibration reduction. Particles have less weight thus this technology applicable in robots, aeroplane structure, spacecraft, rocket launcher, mechanical machinery, civil structure etc. Depending upon the parameter like material properties, size, filling ratio, etc. suppress more vibrations. This paper overview of the particle damping technology for particular applications.

***Keywords*—** **Vibration, Particle damping technology, DEM, Application**

## I. INTRODUCTION

### *A. Vibration*

Vibration are the common problem in machinery industries. Vibration occurs when its equilibrium position has been disturbed. In mechanical field vibration is the major influencing parameter. Energy losses, improper maintenance, reduce the machine lifeline, reduces the performance, failure are the major problem created due of vibration. Due to that mainly vibration will take place. So vibration control is required for particular applications.

- ***Element of vibration***

Vibration can be define as a motion which repeat itself after certain interval of time. Vibration can be categorise in two part free vibration and force vibration. In free vibration if the periodic motion continue after the initial disturbance is removed. In force vibration the motion persist because of disturbing force. The frequency means the period of vibration in the time of single cycle. There are main three element of vibration system (a) Mass M (b) Spring K (c) Damper D. [1]

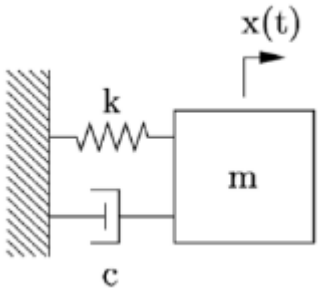


Figure 1 Elements of vibratory system [2]

The working principle of the system, energy is stored in the mass and spring and dissipated the damper in form of heat. The mass element is considered to be rigid body which execute the vibration and lose the kinetic energy. Mass is directly proportional to the change in velocity of body. The spring element has elasticity and assumed to have negligible mass. The damping exists when there is relative motion between the two ends of the damper. [3]

Mainly two types of vibration control technique (a) Active vibration (b) Passive vibration.

***Active damping:*** Active damping achieve great performance. It involves monitoring vibrations of a structure and utilizing the vibration signal to generate a force with the proper phase and amplitude to attenuate the vibration. Piezoelectric material is

used for absorbing energy in the active vibration damping. Basically two types of piezoelectric material used in to control the vibration (a) ceramics (b) polymers. This method also used in sports equipment to reduce the vibration. [4]

***Passive damping:*** Particle damping, viscous fluid, viscoelastic materials, fluids magnets, high damping alloys are material of passive damping. These system control the potential energy of generated by structure. Visco elastic material mostly used in passive damping. It is use to dissipate the energy into heat during interaction. Active damping method widely used in semiconductor industries such as E-beam scopes, wafer profilers, photolithography systems. [4]

The applications for damping systems are space structures, aircraft, automobiles, wafer steppers, electronic components, satellites, marine structures, consumer products, disk drives, and defence systems.

### *B. Particle damping*

Particle damping is to increase damping performance in current technology. Particles are attached to the vibrating structure. The particles take up in kinetic energy of the element and convert it into heat energy with the help of collisions between the particles and the element wall. Energy dissipation occur in the particle damping method due to inelastic and frictional loss collision between particles. Selection of particle damping material having high damping to achieve by converting kinetic energy of the element to heat. [5]

Particle impact damping offers the potential for the design of a better passive damping technique. Passive damping have minimal impact on the strength, stiffness and weight of a vibrating element. With a proper choice of particle material, this technique appears to be independent of temperature and is very durable. Mainly two types of simulation done on particle damping. (a) DEM (Discrete element method) (b) Finite element method. [6]

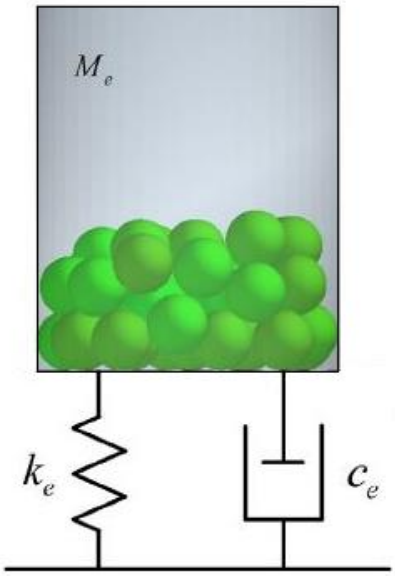


Figure 2 Single degree of freedom particle damper [7]

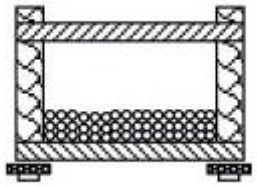

Figure 3 Schematic of particle damper

- ***Advantages***

1. Particle dampers can survive for a long life
2. Without losses of temperature dampers can perform in the large range of temperature.
3. Proper size of the particle can be find through analysis
4. The particles placed inside a cavity in a structure can be less in weight than the mass they replace.

### *C. Particle characteristics*

The working principle of particle technology is simple. Different types of balls material are placed inside the cavity. Cavity are partially and wholly filled. Depending upon the size of the hole, particle size is less than 0.2. So single hole contain numbers of particle in order of 100-500. Selection of high density particles are perform effectively to reduce the vibration.
Packing ratio is the major factor of particle damping method. Packing ratio mainly depend upon the volume of the hole. It is define as space occupied in the hole by particles to the total volume of the hole. [8]

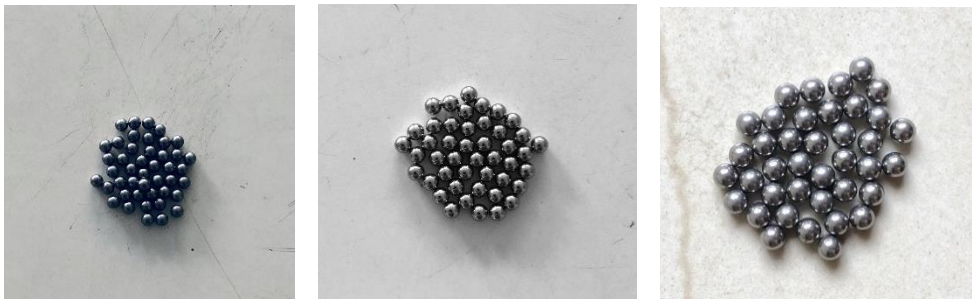

Fig 4(a) 3 mm Fig 4 (b) 4 mm Fig 4 (c) 5 mm

Figure 4 Different size of Particles

Particle are widely used to attenuating mechanical vibration of the system. The use of granular balls in different size, material properties, filling ratio are major influence parameters. Depending upon the size of the hole particle size will be decided. [8]

### *D. Analysis of particle damping*

For analysis of particle damping discrete element method (DEM) has been used. This method is invented by Cundall in 1971. In DEM particle to particle and Particle to wall collision to analyze particle dampers shown in fig. The DEM is a numerical analysis method that can analyze the mechanical behavior of discrete bodies via iterative solutions of step by step. The purpose of Dem analysis is find out the relationship between friction coefficient of particles and energy dissipation of dampers. During simulation all variable are constant except frictional coefficient of particles. For example considering standard discretization sphere as the particles, size of the particles 3 mm, material as stainless steel with density of 7800 kg/m^3, filling rate 70 %. [7]

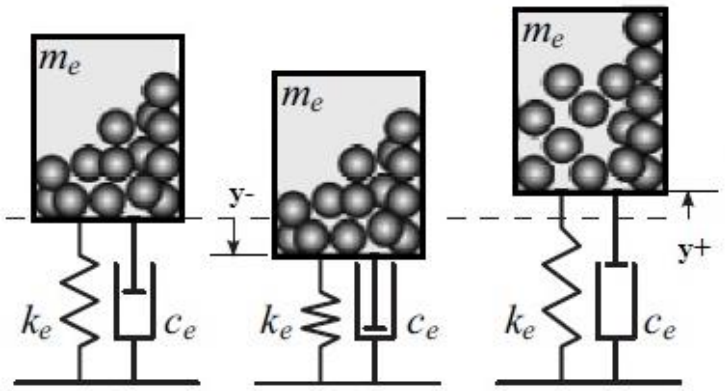


Figure 5 Step and simulation procedure [9]

## II. LITERATURE REVIEW

**Zixin Wang et al, (2018)** studied the current scenario of particle damping technology in the present year. They also studied the basic concept of the particle damping technology, past development history, and which are the main area where research works are going. Researched also specify the overview of mathematical and analytic calculation for particle damping technology. DEM and FEM method used for analysis of particle damping technology. Particle damping technology used in many field like automobile industries, machinery, aeroplane, spacecraft, robotics etc. to reduce the unwanted vibration. [10]

**Liming song et al, (2018)** studied particle damping vibration for vehicular application. Particle damping technology used in the mining dump truck cab to control the vibration by experimentally and simulation method. Overall study conclude that mining dump truck cab vibration effectively reduced by particle damping technology. [11]

**Yanchen Du (2017)** studied spring supported fine particle impact damper for cantilever beam. With the help of particle damping method 80 % amplitude reduction of cantilever beam. Analysis results and experimental results are compare. From analysis, achieve best damping performance with optimal parameter. [12]

**Haseena. A et al, (2015)** studied the multi degree of freedom of structure control by particle damping method. Granular balls are put in the enclose in the multi degree of the structure. When structure vibrates particle undergoes inelastic collision between walls and particles. Due to that high amount of energy dissipated. Overall study conclude that damping parameter such as mass, shape, no of layers etc. effectively reduce the vibration. The use of small size of particle dissipated more energy than large particle. [13]
**Yang Yiqing et al. (2015)** studied on vibration on milling machine. During operation of milling machine vibration is created. So due to that it create poor surface finish, decrease the tool efficiency. Long slander end mills are used for high speed cutting process. The particle damping use in end mills reduce the vibration. [14]

**LI Wei et al. (2014)** purposed the gearbox vibration reduction using particle damping technology. Create a lightning hole on gear and filled the particles into it. During gear rotation particle contact with each other and walls. So that vibration can suppressed. The motor speed, particle ratio, loading condition are major effective parameters of gear vibration analysis. [15]

**Michael Heckel et al, (2012)** investigated that unwanted vibration created during use of surgical and dental instrument which are working on oscillatory mechanism. The particle damping method applied to the instrument reduce the oscillation vibration efficiently. [16]

**B. Sathishkumar et al, (2011)** explained that particle damping is a type of passive damping where numbers of small particles are placed inside the hole of vibrating element or attached to vibrating element. Particle damping is used to increase damping depending upon which type of material used. The feature of particle damping method is that, high damping is achieved by changing kinetic energy of the element to heat. When applied load to the element, particle collision to each other as well as to the element wall. So based on momentum principle particle damping technology work. [17]

**Zheng Lu et al, (2009)** studied the performance of particle damper under harmonic excitation. They presents the concept of momentum exchange between particles at low volumetric ratio. They also evaluate system parameters like particle material, size, mass ratio, damping ratio, coefficient of friction using discrete element simulation method. The use of more particles with high density effectively reduce the vibration. Increase in mass ratio improve the damping performance and reduce the vibration. [18]

**Shulin Wang et al, (2008)** investigated energy dissipated in conventional damping technology due to friction and change of momentum. Use of these damping cannot reduce more vibrations. They studied fine particle impact damper (FPID) for cantilever beam experimentally. From experimentally overall study conclude that FPID reduce 65 % vibration of cantilever beam. To achieve better performance optimal packing ratio is necessary. The comparison between conventional damping and FPID reduce more frequency then the conventional damping. [19]

**Xian-Ming Bai et al (2008)** studied particle damping method for piston based particle damper. The inelastic collisions and friction between balls dissipate the energy. Many parameters like damping performance, material properties, particle size are studied and its effect are analysed by experimentally and simulation. [20]

**W. H. LIAO et al, (2005)** purposed the vibration suppression for bond arm in die bonding machine. In bond arm make cavity to put the particles into that. The experimentation were perform to check the different parameter such as balls size, material, enclose location. Overall study conclude that damping performance of the bond arm vibration effectively reduced by particle damping method. During experiment researcher also investigate damping parameters. [21]

**Kun S. Marhadi, (2005)** studied particle damping measure for cantilever beam. Lead, steel, glass, tungsten carbide, steel dust, sand dust are used in the experiment. Overall study conclude that the effect of mass ratio, particle size, packing ratio are the major parameter of the particle damping technology. [22]

**Michael Yu Wang, (2004)** explain the computer simulation of particle damping using Discrete element method. Discrete element method can analyse the motions of multi bodies and energy dissipation. They perform experiment and validate the result with simulation system. Overall study conclude that particle damping is mixture of impact and friction damping mechanism. [23]

**Stepan S. Simonian (2004),** studied the acceleration damping technology for different application to absorb the kinetic energy and reduce the vibration. Particle are filled into the holes to the vibration structure. The material of the particles are metallic, ceramics, polymer and mixture of various material. Practical were performed on different application like cantilever beam, bond arm etc. Overall study conclude that particle absorb the kinetic energy and convert into heat through collision between particles and wall. [24]

**K.W. Chan et al, (2004),** perform experiment on three structural object steel beam, bond arm and bond head stand. Number of experiments are perform with consider different parameter for vibration reduction of object. Depending upon structure parameters of particle selected. The use of particle damping effectively reduce the vibration for particular application. [25]

**R. D. FRIEND et al, (2000)** studied the particle damping technology experimentally. Cantilever beam is in the experiment. Material of beam is aluminium. They put particle at the end of the beam and analyse the result mathematically and analytically. Overall study conclude that, focusing on the dissipation on kinetic energy. With particle and without particle there are major difference in the beam vibration. With particle reduce more vibration compare to without particles. Experiment done many times to check various parameter for dissipate maximum energy. Use of small particle high damping achieved. [26]

## III.CONCLUSION

This study review of the passive vibration particle damping technology for the different engineering field. Particle like steel, tungsten carbide, copper having high density are reduce vibration effectively. Selection of proper amount of packing ratio, size, material properties etc. are the major parameters of particle damping technology. The Discrete Element Method (DEM) method is widely used for particle damping analysis. The Discrete Element Method (DEM) is a particle-scale numerical method for modelling the bulk behavior of granular materials.

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