A REVIEW OF PARTICLE IMPACT DAMPING FOR VIBRATION MITIGAION

Amol Y.Wadghule[1], S.P.Deshpande[2]

[1]*P.G.student, Department of Mechanical Engineering, Gokhale education society's R.H.Sapat C.O.E.,Maharashtra, India*

[2]*Assistant Professor, Department of Mechanical Engineering, Gokhale education society's R.H.Sapat C.O.E.,Maharashtra, India*

ABSTRACT

There are various machining operations such as boring, turning which are widely used in industry. In such operations dimensional accuracy, surface finish are some of the important attributes from customer point of view. To meet them it is important to control factors which deteriorate its value such as speed, depth of cut, vibration etc. Much work is being done to control adverse effect of speed, depth of cut on accuracy, surface finish but last factor that is vibration is having adverse impact if ignored. So, it is required to be minimized. So to reduce vibrations there are various damping techniques which can be mainly categorized as active and passive damping. Among these active damping requires cumbersome arrangement along with sensors which finally increases cost. On other hand passive damping can be easily combined with vibrating structure. There are various passive damping techniques such as viscous damping, viscoelastic damping etc. but each of it have certain limitations which may be environmental conditions or temperature variations or attachment with vibrating structure without changing its characteristics(such as its stiffness, weight etc.).So recently developed particle impact damping (PID) is proving to be one of the most promising technique which overcomes most of the limitations of above said passive damping techniques which is being reviewed in this paper

Keyword : - *Passive damping, Boring, Turning, Vibration, Surface Roughness.*

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1. Introduction

Particle impact damping (PID) is a method to increase structural damping by inserting particles in an enclosure attached to a vibrating structure. The particles absorb kinetic energy of the structure and convert it into heat through inelastic collisions between the particles and the enclosure. Additional energy dissipation may also occur due to frictional losses and inelastic particle-to-particle collisions amongst the particles.

The unique aspect of PID is that high damping is achieved by converting kinetic energy of the structure to heat as opposed to the more traditional methods of damping where the elastic strain energy stored in the structure is converted to heat.

Viscoelastic materials have wide applications in vibration damping in a normal environment, i.e. under ambient temperature and pressure. However, they lose their effectiveness in very low and high temperature environments and degrade over time. Particle impact damping offers the potential for the design of a better passive damping technique with minimal impact on the strength, stiffness and weight of a vibrating structure. With a proper choice of particle material, this technique appears to be independent of temperature and is very durable. Earlier studies have investigated the energy loss mechanisms and characteristic of particle impact dampers under various excitation models.

2. Literature Review

S. Devaraj et al., (2014) proposed fine particle impact damping method in boring operation for surface quality enrichment of the work piece. Damping to suppress the vibrations was provided by embedding fine particles within small hole of a vibrating structure. Authors performed experimental investigation for the surface roughness measurement of work pieces using Copper, Aluminum, Zinc and Silicon particles but having different densities. The results obtained proved that the usage of silicon and zinc particles showed less damping capability when compared to the damping capabilities of the boring tool using Copper and Aluminum particles and thus it revealed that the surface finish value of the work piece can be improved using particle impact damping

Pranali Khatake et al., (2013) introduced a vibration attenuation technique for boring bar through the implementation of passive damper. Researchers 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.

Zhehe Yao et al., (2011) worked on chatter suppression by parametric excitation. In this study, the effect of parametric excitation on a van der Pol–Duffing oscillator with a time delay feedback was studied using the averaging method. It involves the validation of the effect of parametric excitation on chatter suppression through the cutting experiments using Magneto-Rheological (MR) fluid-controlled boring bar. The effect of parametric excitation on the self-excited vibration system was studied regardless of the generation mechanisms of the self-excited vibration. The regenerative effect is the most common effect that generates chatter in the machining processes. Therefore, researcher studied the regenerative effect for the stability analysis of the cutting vibration system. Parametric excitation effects on chatter suppression were investigated by experimental validation and theoretical analysis. The cutting experiments using magneto-rheological fluid controlled boring bar showed remarkable effects on chatter suppression.

M. Senthil kumar et al., (2011) worked on particle damping technique for the control of vibrations in boring bar. He investigated the efficiency of particle damping in vibration attenuation of boring bar using damping particles like copper and lead. In this regard, Boring bar is drilled to have a longitudinal hole in which damping particles were embedded. Experimental investigations were carried out to find out the settling time of boring bar for different particles by giving an impact pulse by an impact hammer to the bar held as a cantilever beam. Damping performances of these particles having various sizes were observed and compared .Natural frequencies of the solid boring bar acting as a beam were compared with those of the drilled boring bar

Henrik Akesson et al., (2009) concentrated on studying the various clamping conditions of boring tool. Authors worked on the effect of different clamping properties on the dynamic properties of clamped boring bars and discussed about Euler Bernoulli modeling of clamped boring bar with emphasis on the modeling of the clamping conditions. Experimental investigation results show variation in dynamic characteristics of boring bar as per the changes in the clamping positions of boring bar is investigated experimentally. Standard and modified boring bars are considered. The influence of standard coupling housings with different number of clamping screws, different clamping screw diameters, different screw tightening torques, on Eigen frequency values and its mode shapes orientation in cutting speed, cutting depth plane was calculated.

Zhiwei Xu et al., (2009) investigated a structure in which damping particles were embedded in the horizontal hole drilled in the vibrating structure. Authors concentrated on the study of shear of the boring bar and its effects on the damping capability of the structure and also presented an analytical model to analyze the effect of particle damping on vibration behavior of boring bar. I It includes the different volumetric ratios of particles and also different types of particles and their various sizes to observe the damping effect of each and to suggest a good damping material for better vibration reduction. The passive damping using damping particles is proved to be effective. Although it is non-linear, it can give a strong energy dissipation rate

Deqing Mei et al., (2009) proposed an MR fluid-controlled chatter suppressing boring Bar. Authors established a dynamic model of an MR fluid-controlled boring bar based on an Euler–Bernoulli beam model. FEM analysis was applied for designing the magnetic field and analyzed the regions of operating stability using the dynamic beam model also concluded that it can be used to suppress the chatter by adjusting the damping and natural frequency of the system. Experimental results regarding the vibrations at the structure's tip in different spindle speeds validated the model and demonstrated chatter suppression in a boring process and reduced the chatter

B.Moetakef-Imani et al., (2009) presented the dynamic simulation of boring process and also presented a model for simulation. Author studied the causes of vibration and vibration behavior of boring bar for certain cutting conditions and revealed that boring bar is easily subjected to vibrations because of its large slenderness ratio. Author used B-spline parametric curves to simulate different tool geometries with a single approach. Euler-Bernoulli Beam theory was used for boring bar modeling and stated that the structure comprising of lathe machine, boring tool and the work-piece undergo excessive vibrations under certain conditions

C. V. Biju, (2009) focused on investigation into the effect of passive damping technique using damping particles on surface topography when boring operation is being processed. For this purpose author used a particle damping method called the novel method, for vibration control during boring process and modeled the boring bars without cavity and with cavity and analyzed using Ansys. Spherical steel particles were used as damping particles in a cavity near machining end of the designed boring bar. Damping characteristics of the boring bar were evaluated for varying sizes and volumetric ratios of damping particles using impact and shaker tests and results were included. Results of experimentation in terms of surface roughness and chatter marks were analyzed and the results showed an improvement of bore quality with particle impact damping as compared with a boring bar without particle impact damping (PID). Shaker tests revealed that 3.17 mm sized steel damping particles with 50% volume fraction reduce the amplitude response of boring bar. Author showed that the transfer of momentum from the vibratory system to the damping particles and the energy dissipation caused by collision between the particles and cavity reduce the self-excited vibration of boring bar thereby improving the stability of boring operation.

Steven Olson et al., (2003) established an analytical particle damping model. It involves an analytical evaluation of the particle damper and 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

Friend and Kinra, (2000) conducted a study of particle impact damping in the context of free decay of a cantilever beam in the vertical plane. In their study, particle impact damping (PID) was measured for a cantilever beam with the enclosure attached to its free end. Lead powder was used throughout the study and also studied the effects of vibration amplitude and particle fill ratio (or clearance) on damping. PID was observed to be highly nonlinear, i.e. amplitude dependent. A very high value of maximum specific damping capacity (50%) was achieved in the experiment. An elementary analytical model was also constructed to capture the essential physics of particle impact damping. A satisfactory agreement between the theory and experiment was observed. This work is a continuation of the work by Friend and Kinra. The primary objective of this work is to expand the previous experiments in order to collect PID characteristics of various particle materials and particle sizes. Using the same method and experimental procedures developed by Friend and Kinra, experiments are conducted for lead spheres, steel spheres, glass spheres, sand, steel dust, lead dust, and tungsten carbide pellets. The particle diameter varies from about 0.2 mm to 3 mm. Tests are conducted for different vibration amplitudes, clearances, and number of particles.

Hollkamp and Gordon, (1998) tested a cantilever beam with eight holes along its length which are filled with particles with variation of particle materials sizes and packing ratio. Experimentation reveals that particle material and shape had little influence compared with packing ratio and excitation amplitude. Also an important observation was made that damping increased with amplitude up to a maximum and then decreased if amplitude increased further.

Saluena et al., (1998) used the discrete element method to model three phases or regimes of damping that is solid, liquid and gas. Results showed that solid regime occurs when the particles move together with no relative motion between particles. The fluid regime is characterized by formation of convection pattern and gas is by unpredictable motion of individual particles. Maximum damping occurs at fluidization point which is less in liquid regime and increases in the gas regime.

Papalou and Masri, (1998) carried out a wide range of experimentation with PD under vertically and horizontally vibrating systems with random excitation. Along with this they have also studied the effect of mass ratio, particle size, container box dimensions, excitation levels, direction of excitation and proposed design procedures based on equivalent single particle damper. From experimentation results obtained showed that there was an optimum length/width aspect ratio and void space inside container. Also it was found that optimally designed single particle damper is more efficient than multi particle damper of equal mass

Panossian, (1992) conducted a study of non-obstructive particle damping in the modal analysis of structures at a higher frequency range of 300 Hz to 5,000 Hz. This method consists of drilling small diameter cavities at appropriate locations in a structure and partially or fully filling the holes with particles of different materials and sizes (steel shot, tungsten powder, nickel powder, etc.). Significant decrease in structural vibrations was observed even when the holes were completely filled with particles and subjected to a pressure as high as 240 atmospheres.

Masri S.F. and Caughey T.K, (1969) performed the extensive study of impact dampers and defined that impact per cycle as “stable” type of motion. Also determined the exact solution for a damped, single degree of freedom system with sinusoidal excitation and analyzed its stability. Results defined the stable regions of solution. Also presented a solution of system using multiple unit impact dampers. Experimented with multidegree of freedom system and found out the exact solution for steady state motion of system in response to sinusoidal excitation.

Leiber and Jensen, (1944) For the first time suggested the use of such a system in 1944.Also find out the response of the undamped, single degree of freedom system with a single active acceleration damper. Initially assumption was that response of the system to a sinusoidal forcing function was simple harmonic motion and that in every cycle two completely plastic impacts occurred. Authors also reported that the travel path of the particle is 'n' times the amplitude response for maximum energy dissipation.

4. CONCLUSIONS

This review paper reveals that, recently particle impact damping is getting more importance as it is

a) Easy to construct

b) Compact in construction

c) Insensitive to temperature variations

d) Durability is high

e) It can be easily combined with vibrating structure with least modification of structure stiffness, weight etc. and such various benefits over other passive damping techniques.

But irrespective of these benefits there are certain areas which are required to be focused so that it can be used on large scale at commercial level. Such areas include,

More research work is required to be carried out in relation with variation of vibrating characteristics of particle impact damping under various conditions like varying excitation force of vibrating structure. Also more work is required to be done in area that which particle damping combination(its particle size, volumetric packing ratio, particle material density) is optimum to reduce vibrations to its minimum value for given application.

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