A Review on an Effective Implementation of Particle Impact Damper to Suppress the Vibrations for Different Applications

Prafull P. Kasar[1], Atul S. Aradhye[2]

[1,2]M.E. Scholar, Department of Mechanical Engineering, SKN Sinhgad College of Engineering, Korti Pandharpur, India

---***---

Abstract – *Problems involving vibrations occur in most of the fields of engineering. The presence of unwanted vibrations in a structure must often be overcome to avoid damage and eventual failure. The vibration damping is passive vibration control technique, which is mostly used to control and minimize excess vibrations in structural system. In case of particle impact damping (PID), an impact mass is rigidly attached to the main vibrating structure to attenuate 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 momentum and friction in between main mass and impact mass. Particle impact dampers are used to reduce the undesirable vibration in many applications. This paper presents a review on particle impact damping technique 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.*

Key Words: Vibration, Damping, Impact, Application.

1. INTRODUCTION

Vibration is a phenomenon in which oscillations or movement of part occurs about equilibrium position. Sometimes vibration can be desirable such as the motion of a tuning fork, fettling operation, testing equipment's, hoppers and conveyors. And in some cases vibrations are undesirable too such as, vibrations in aircrafts, vibrations in multi- storey buildings and bridges, forging operations, milling and grinding operations, high speed cutting machine. The vibrations produced in machine while carrying out different machining operations are mostly undesirable as they produce stresses in machine parts, induce fatigue and absorbs the energy from the system itself. These excessive vibrations need to be reduced to avoid damage and failure of the parts.

When the amplitude of these vibrations exceeds the permissible limit, the failure of structure occurs. Vibration causes rapid wear and tear of parts. Many buildings, bridges also fall due to vibration. If excitation frequency coincides with natural frequency of main system, a condition of resonance is reached and dangerously, large oscillations may occur. This may result in mechanical failure of system.

So to avoid such condition one must be aware of technique to reduce these excessive vibrations. Keeping in view all these diverting effects, it is necessary to minimize vibrational effect over mechanical components. The particle impact damping is an effective as well as efficient technique to control and reduce the vibrations in many applications. This review focuses on different applications where particle impact technique is successfully used to suppress vibrations.

1.1 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.

1.2 Particle Impact Damping

Impact dampers are designed to damp a specific frequency. Impact damping is a passive vibration control technique for lightly damped resonant structures. Conventionally, a small ball with practically no resilience is employed as an impact damper. It is placed inside a slightly larger container, which is rigidly attached to the resonant system called the primary system. A conventional impact damper system is as shown in Figure 1.

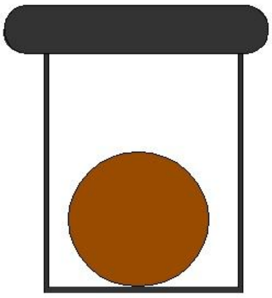

Fig -1: Metal particle as damping material in an enclosure

In case of particle impact damping (PID), an impact mass is rigidly attached to the main vibrating structure to attenuate the vibrations. The impact mass either contains single particle or number of particles. It is one of the passive control methods which makes the use of an impact damper in which repeated impacts of a small moving mass on the main structure are used to control the vibrations which is random in nature.

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.

2. LITERATURE REVIEW

L. Chen et al. (1993) had stated that, in almost all branches of an industry, the robotic applications are becoming popular. When a robot arm is moving at high speed between the work stations and the arm is suddenly stopped after achieving new position, the arm causes transient vibrations of large amplitude. The inherent light damping of structure requires some idle time for attenuation of excessive transient vibrations, so that the arm can be moved to perform new task. But we require high production rate, with high speed but also minimum energy to actuate or handle the robot. An impact damping technique is applied to minimize the excessive transient vibrations of a flexible structure like robot arm. The research shows excessive transient vibrations are controlled by using an impact damping technique. The research concluded that the excessive transient vibration starts attenuating if impact takes place in vertical directions [1].

S.Ema et al. (1996) had done experimentation in order to find out damping characteristics of impact damper when the main vibratory system was vibrated in direction of gravity and perpendicular to it. Further it is applied to improve damping capabilities of drills. The experimentation also shows that the frequency of vibratory system with an impact mass damper also depends upon natural frequency of the system and the mass ratio. The investigation also proved that it is possible to apply the impact damper to the actual cutting tool and use of impact damper can improve the damping capabilities of main vibratory system [2].

K-Ogawa et al. (1997) had evaluated that a cable strayed bridge pylon may get influenced and affected by wind, inducing vibrations in cable. For the cable-stayed Funchu lake bridge in Japan, which is 196.7m, an impact mass damper was designed to minimize wind induced vibration of pylon. The impact mass damper found to be more effective in order to suppress wind induced vibration in a cable stayed bridge pylon. The collision between impact damper mass and neoprene rubber cushion does not produce in impulsive bending stress in pylon as well as it does not produce undesirable noise [3].

H. Cao et al. (1998) had designed an active mass damper in order to reduce effects of wind vibrations on a tall (340 m) communication tower in Nanjing, China. Active mass damper had been designed in accordance with space strength and power limitations. The existing was having excessive vibrations under design of wind loads beyond the comfort level. Design of an active mass damper to reduce excessive vibrations is economical with high performance within specified constrained [4].

Satoshi Ema et al. (2000) had investigated the impact damper to improve damping capabilities of boring tools and suppression of chatter vibration. The damping capability of boring tools is considerably improved using impact damper. In practical use an impact damper can be applied on the face flank of boring tool to suppress the vibrations. It is possible to bore a deeper hole as compared with boring tools available in the market. By using an impact damper, the efficiency of boring operation will be improved. Impact dampers can suppress the vibrations of boring tools in vertical directions but hardly suppress it in the horizontal direction [5].

Yasunori Wakasawa et al. (2004) had proposed an effective way to improve damping capacity of machine tool structure .He had also investigated that damping capacity of machine tool structure packed with balls affected by ball size, magnitude of impulse, packed ball material and structure size. The ball size is the most influencing parameter for damping the vibrations. In order to investigate the damping capacity of machine tool structure packed with balls some experiments are carried out by widely varying packing ratio, impulse force, structure size and packed ball material.50 % of packing ratio is optimal. The damping capacity can be improved by increasing packed ball weight [6].

Zhiwei Xu et al. (2007) had reported 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. The particles absorb kinetic energy through particle-to-wall and particle-to-particle frictional collisions. Vibration and noise problems can be solved with this simple technique. A successful application of particle damping for noise reduction is reported [7].

M. Senthil kumar et al. (2011) had expressed that particle damping is an attractive passive damping technique due to its simplicity, cost-effectiveness, as well as temperature and degradation insensitivity. The research investigated particle impact damping technique to control the vibrations in boring bar by using copper and lead particles of various sizes. The efficiency of particle damping in boring bar had been studied and found that particle damping is an effective technique. Particle damping behaves in nonlinear manner and concluded that amount of damping as well as maximum frequency at which damping occurs depends upon the properties of material [8].

Michael Heckel et al. (2012) investigated that, the instruments used for surgical and dental application with an oscillation mechanism produces unwanted vibrations to the operator's hand. Many times the weight of the instrument's body is increased in order to damp the produced vibrations. On his recent research related to the optimization of granular damping, he had developed a prototype granular damper which will attenuate the vibrations of an oscillatory saw. The attenuation in vibration was found to be twice as efficient as comparable solid mass. He had concluded and found that granular dampers operate more efficiently than solid mass dampers if the geometry of the dampers is optimized with respect to the specific amplitude of the vibration. Consequently, by means of granular dampers one can achieve either more efficient damping while keeping the total weight of the saw invariant or alternatively the weight of the saw can be reduced by keeping the residual vibration of the handle constant [9].

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 [10].

P.Veeramuthuvel et al. (2016) had presented a novel application of particle damper on electronic packages of spacecraft. During the launch, the performance of particle damper of the electronic applications for spacecraft application is studied. These electronic packages experience a severe dynamic response due to high intensity vibrations and shocks during the launch phase. To overcome the failure of electronic package during the launching, particle damping technique is used. The response for reduction in vibration was significant. The comparison of particle damper effectiveness under random vibration with respect to shape of particle damper capsule and packing ratio is also examined [11].

3. CONCLUSIONS

This review expresses that particle impact damping is an effective and efficient technique to suppress the vibrations. The review also focuses on particle impact technology had been developed and used for many engineering applications. The damping technique not only reduces the vibrations but also improves the damping ability of structure. Hence the failure of machine part or structure is avoided, extending the life of structure.

The review expresses successful application of particle impact damper such as cable stayed bridge pylon in Japan, a tall TV tower in Nanjing China, robotic application etc.

The impact damping technique improves the damping capabilities of drills, boring tools along with machine tool structure. The vibrations in the instruments used for surgical and dental application can be reduced by effective implementation of damping method. Recently a novel application of particle damper is applied on an electronic package of spacecraft.

ACKNOWLEDGEMENT

I am very thankful and grateful to my project guide A.S. Aradhye Assistant professor, Mechanical Engineering Department, SKN Sinhgad College of Engineering Korti, Pandharpur, Maharashtra, India, for imparting valuable knowledge of impact damping as well as continuous encouragement and inspiration for completing this work.

REFERENCES

[1] L. Chen, S. E. Semercigil, "A beam like damper for attenuating vibrations of light structures", Journal of Sound and vibration 164(1), 53-65, 1993.

[2] S.Ema, E.Marui, "Damping characteristics of an impact damper and its application", Int. J. Mach Tools Manufact. Vol 36 No.3, PP 293-306, 1996.

[3] K-Ogawa, T ide, T-saitou, "Application of impact mass damper to a cable stayed bridge pylon", Journal of wind engineering and industrial aerodynamics 72, 301-312, 1997.

[4] H.Cao, A.M.Reinhorn, T.T.Soong, "Design of an active mass damper for a tall TV tower in Nanjing China", Engineering Structures vol 20, No.3, pp 134-143, 1998.

[5] Satoshi Ema, Etsuo Marui, “Suppression of chatter vibration of boring tools using impact dampers”, International Journal of Machine Tools & Manufacture 40, 1141–1156, 2000.

[6] Yasunori Wakasawa, Masatoshi Hashimoto, Etsuo Marui, “The damping capacity improvement of machine tool structures by ball packing”, International Journal of Machine Tools & Manufacture 44,1527–1536,2004.

[7] Zhiwei Xu, Michael Yu Wang and Tianning Chen, “Particle damping for vibration and noise reduction”, ICSV14 Cairns Australia 9-12 July, 2007.

[8] M. Senthil kumar, K. M. Mohanasundaram, B. Sathishkumar, “A case study on vibration control in a boring bar using particle damping”, International Journal of Engineering, Science and Technology Vol. 3, No. 8, pp. 177-184, 2011.

[9] Michael Heckel, Achim Sack, Jonathan E. Kollmer, Thorsten Poschel, “Granular dampers for the reduction of vibrations of an oscillatory saw”, Physical A 391, 4442–4447, 2012.

[10] Yang Yiqing, Yu Yu, “Design and Simulation of Long Slender end Mill Embedded with Passive Damper”, Procedia Engineering 99 ,1380 – 1384, 2015.

[11] P.Veeramuthuvel, K.Shankar, K.K.Sairajan, “Application of particle damper on electronic packages for spacecraft”, Acta Astronautica127,260–270, 2016.