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Effect of Cavity Size on Performance of Particle Damper

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Abstract: Particle damping is a damping technique that has found wide applications in engineering systems. It is a form of damping where the energy dissipation is achieved through the motion of small particles within a cavity. This technique has several unique features that make it an attractive option for many engineering applications. Cantilever beam with FFT analyzer is used to find the response parameters. The readings are taken with varying cavity dimensions, size of ball, packing ratio and ball material. The readings in the form of acceleration are noted by varying one experimental parameter. From the experimentation it is found that 24 mm diameter and height 37 mm cavity with 50% Packing ratio is effective for the applied experimental set-up.
Keywords: Transient Vibration, Particle damping, cantilever beam, Cavity size, single-degree-of-freedom.

I. INTRODUCTION

Particle damping is a fundamental concept in engineering that has important implications for the design and performance of many physical systems, ranging from large structures such as bridges and buildings to small-scale systems such as micro electromechanical systems (MEMS). The study of particle damping involves the understanding of the various forces and mechanisms that cause energy to be lost from vibrating systems, leading to the reduction of their amplitudes over time.

In the field of mechanical engineering, particle damping is particularly important for the design and optimization of mechanical systems, such as bearings, gears, and machines. Frictional damping, one of the most well-known forms of particle damping, is a key factor that affects the efficiency and performance of these systems. By understanding the mechanisms of frictional damping and modeling its effects, engineers can design and optimize systems to minimize friction and increase efficiency. In the field of structural engineering, particle damping plays a crucial role in the design and analysis of large structures, such as bridges and buildings. The study of particle damping in these structures helps engineers to understand the behavior of vibrating systems and to design structures that are stable, safe, and efficient. This involves the use of mathematical models that describe the behavior of vibrating systems, as well as the use of experimental techniques to measure the damping properties of materials and structures. In the field of materials science, particle damping is used to study the mechanical properties of materials, such as the damping capacity of various materials and the relationship between damping and other material properties, such as stiffness and strength. This information can then be used to design and optimize the performance of materials for various applications, such as structural materials for bridges and buildings. Particle damping is also important for the design of control systems in engineering. Active damping techniques, which involve the use of control systems to actively reduce the amplitude of vibrations in a system, are increasingly being used in a variety of physical systems, including bridges, buildings, and MEMS. The use of these techniques requires a deep understanding of the underlying mechanisms of particle damping and the ability to model and control these effects. In conclusion, particle damping is a fundamental and widely studied concept in engineering that has important implications for the design and performance of many physical systems. Ongoing research in this field will likely lead to new and improved methods for controlling the behavior of physical systems, optimizing the performance of materials, and enhancing the safety and efficiency of structures.

II. LITERATURE REVIEW

Xiao Has done dynamic analysis and experimental verification on extension housing for printed circuit board based on particle damping material. The study is based on to develop and design a new type of vibration reduction technology. By harmonic response analysis based on extension system they found that the peak frequency of extension system could be obtained and installation position of particle damper is determined. They have used ANSYS finite element software for 3D structure of solid element. They found that filling rate was 96% and best vibration reduction effect can reach 57.90%.

They conclude that effect of vibration reduction is for less than the sensitive area of vibration transfer path .And this design method is completely suitable in harsh environment. [1] K.B. Sachidananda Studied the effect of powder particle size on vibration damping. They have done experimental analysis by using dynamic mechanical analyzer (DMA). The surface morphology of the coating were studied using scanning electron microscope (SEM). In this analysis they found that the damping values were found to be increased with the increase in particle size in the measured strain range. The behavior was correlated with the microstructure investigated by SEM. [2] Louis has done modeling and testing particle damper used on beam. Analysis is done by DEM simulation software. These research shows overview on their advantages, modeling techniques, design consideration and experimental analysis. The emphasis is on particle dampers used on beam vibrating at frequencies between 10HZ and 1KHZ. [3] Hang ye Has done experimental study on damping effect of multiunit particle dampers which is applied to bracket structure. In this, Discrete element method (DEM) and experimental approach is used. With the help of fem ANSYS analysis is done. In this, The effect of additional structural quality, particle material and filling factor of particle damper on the damping effect is investigated by experiment. In this they found that, with the same filling factor, The tungsten carbide powder has the best damping effect. [4] Shinde Studied on particle damping technique for vibration suppression. With mathematical modeling experiments is done. This study reveals that passive damping technique by using damping particle like steel, plastic, granules etc. can suppress the vibration. [5] Meyer studied the damping behavior of particle dampers attached to a vibrating structure. In this, numerical and experimental analysis is done on vibrating structure. In this, a discrete element model is combined with a reduced finite element model and it can be analyzed for a wide frequency range. An efficient contact algorithm is used while a coupling with a FEM. [6] Marhadi Studied on particle impact damping for cantilevered beam with particle filled enclosure attached to its free end. They have done theoretical analysis and experimental analysis on cantilever beam. They also studied the effect of mass ratio, effect of number of particles and effect of particle material. Five materials have been tested: lead, steel, glass, tungsten carbide and sand. By experiment they conclude that particle impact damping (PID) must include size and number of particles as additional independent parameter. [7] Bai Studied on particle dynamic simulation of a piston based particle damper. They have proposed piston based particle damper geometry and investigated using experiments and particle dynamic simulation. They have done experimental setup on particle based thrust damper. The simulation results were compared and validated with experimental setup. Their results shows that high damping capacity can be achieved in piston based particle damper. The particle size effect was also investigated in this simulation. [8] Zheng Lu studied the performance of particle dampers under dynamic loads. They have done systematic investigation of the performance of particle dampers attached to primary system and multi degree of freedom under different dynamics loads. Discrete element method is used for analysis. This study investigated the performance of a vertical particle damper under free vibrations. [9] Zhang studied Damping Characteristics of Cantilever Beam with Obstacle Grid Particle Dampers. They conduct Experimental setup and simulated studies.

In this they uses discrete element Software (EDEM) to simulate and model the particle dampers with and without the obstacle gird. In this they found that with increase of excitation amplitude, damping effect of traditional particle damper is 10.7 dB, 7.1 dB, 4.6 dB and 2.9 dB, respectively. And conventional particle dampers reduce the level of vibration energy transfer and dissipation due to fluidization of particles. [10] Tobias studied Design of Particle Dampers for laser powder bed fusion. In this they found that manufactured particle dampers can significantly improve component damping. If designed incorrectly, the damping can be worsened. So they done a Experimental Methodology for that and conducted experiments. And they found positive effect of the particle damping in a frequency range from 500 to 30,000 HZ.[11] Allan studied and done comparison of two methods generally used to treat unwanted vibration in vehicles. They have done laboratory work to measure and compare effectiveness of common designs for practical tuned mass dampers.

In this they found that Tuned mass dampers and particle dampers of equal mass have similar performance potential. They found that particle damper filled with lead spheres was 60.6% is effective and particle damper filled with iron powder was 52.2% is found effective. In this it is seen that particle damping is effective over a range of excitation, but it has poor control if excitation is too high or too low.[12] Yanchen Du done experimental setup on spring-supported fine particle impact damper in which they integrates the effects of elastic deformation and plastic deformation on cantilever beam. In this experiment they found that particle impact damper reduces 80% of the maximum amplitude of cantilever beam. In this they done experimental study and theoretical modeling. To achieve the best performance they found that 0.15 clearance ratio and 0.007 of stiffness ratio is best.[13] Niklas Meyer they have done experimental setup to find damping prediction of particle dampers for structures under forced vibration using effective fields. In this with this model using FEM and model reduction techniques they found exact results. In this they found that there are two major approaches exist to analyze particle dampers by either energy dissipation inside the particle damper or particle damper is coupled to a structure and the overall damping ratio is determined.[14]

III. EXPERIMENTAL SETUP

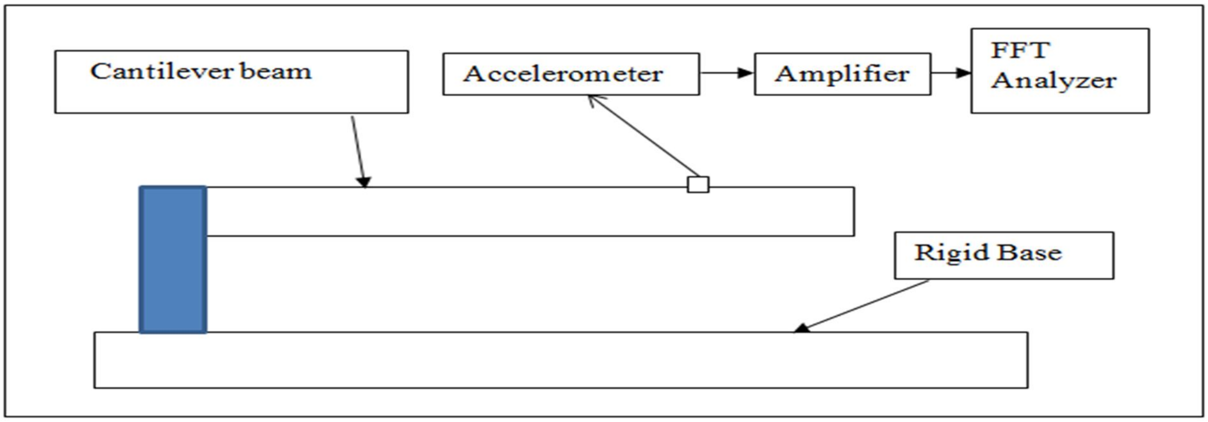

Fig.1 Experimental setup

Fig.1, shows the experimental apparatus used in this study. The experimental apparatus consists of the primary structure, and acts as an equivalent single-degree-of-freedom system. The structure is like a cantilever beam. The particle damper consists of three cylindrical cavities. To investigate the effect of the cavity diameter and packing ratio, ball size and ball material on the damping efficiency. The cavities are partially filled with granular particles of the same size. Readings for acceleration are taken with the help of FFT analyzer for transient.

IV. EXPERIMENTATION

In this first case, we will try to find out the effect of cavity size on the performance of damper. Total 9 experiments are carried out varying the remaining parameters. In this experimentation, ball size used are 4 mm, 5 mm and 6 mm. The first experiment is carried out with ball size 4 mm with ball material mild steel. The cavity size and packing ratio is varied to find the acceleration. The second experiment is carried out with ball size 4 mm with ball material plastic. The cavity size and packing ratio is varied to find the acceleration. The third experiment is carried out with ball size 4 mm with ball material sand. The cavity size and packing ratio is varied to find the acceleration. The fourth experiment is carried out with ball size 5 mm with ball material mild steel. The cavity size and packing ratio is varied to find the acceleration. The fifth experiment is carried out with ball size 5 mm with ball material plastic. The cavity size and packing ratio is varied to find the acceleration. The sixth experiment is carried out with ball size 5 mm with ball material sand. The cavity size and packing ratio is varied to find the acceleration. The seventh experiment is carried out with ball size 6 mm with ball material mild steel. The cavity size and packing ratio is varied to find the acceleration. The eighth experiment is carried out with ball size 6 mm with ball material plastic. The cavity size and packing ratio is varied to find the acceleration. The ninth experiment is carried out with ball size 6 mm with ball material sand. The cavity size and packing ratio is varied to find the acceleration.

V. RESULTS

The results of all the experiments are given as bellow.

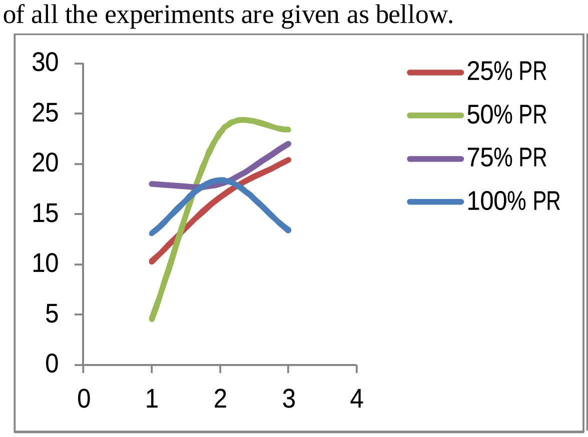

Fig.2

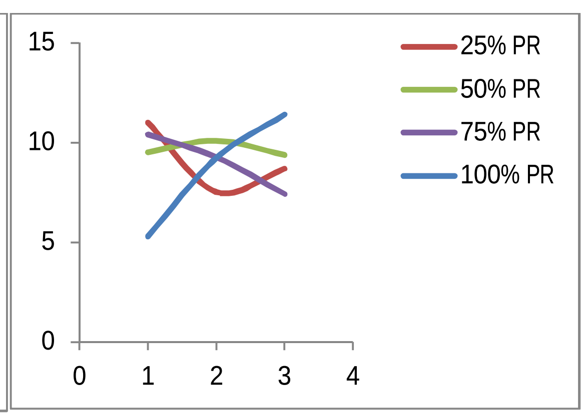

Fig.3

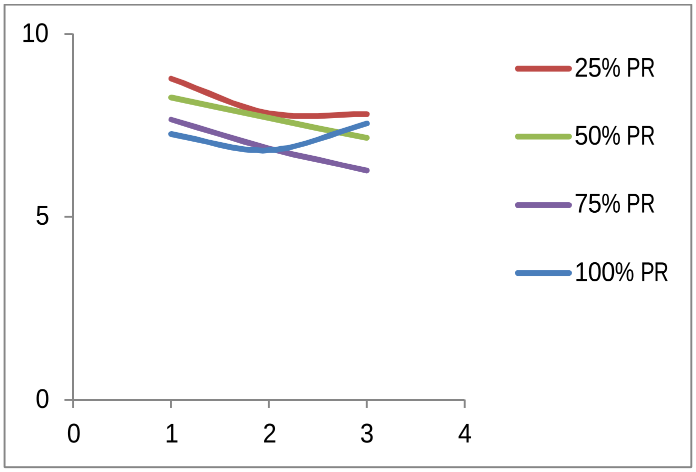

Fig.4

In the first experiment, as shown in (Fig. 2) the maximum damping is found for 50% PR with cavity size 24 mm diameter and height 37mm. the minimum damping is found for 50% PR with Cavity size 32 mm diameter and height 56 mm. Here, 24 mm diameter and height 37 mm with 50% PR is effective. In which energy loss due to impact energy is found more than energy loss due to friction in between ball to ball and ball to cavity. In the second experiment, as shown in (Fig.3) the maximum damping is found for 100% PR with cavity size 24 mm diameter and height 37 mm. the minimum damping is found for 100% PR with cavity size 32 mm diameter and height 56 mm. Here, 24 mm diameter and height 37 mm with 100% PR is found effective. In which energy loss due to friction in between ball to ball and ball to cavity is found more. In the third experiment, as shown in (Fig.4) the maximum damping is found for 75% PR with cavity size 32 mm diameter and height 56 mm. the minimum damping is found for 25% PR with cavity size 24 mm diameter and height 37 mm. Here, 32 mm diameter and height 56 mm with 75% PR is effective. In which energy loss due to friction in between ball to ball and ball to cavity is found more.

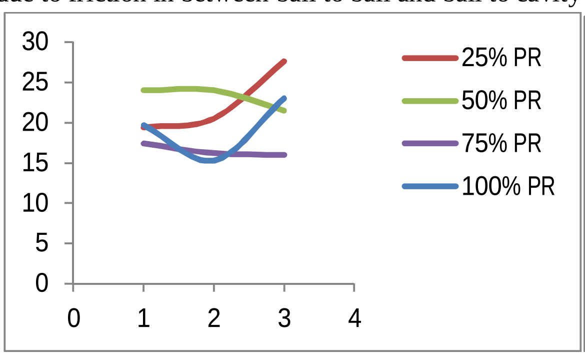

Fig.5

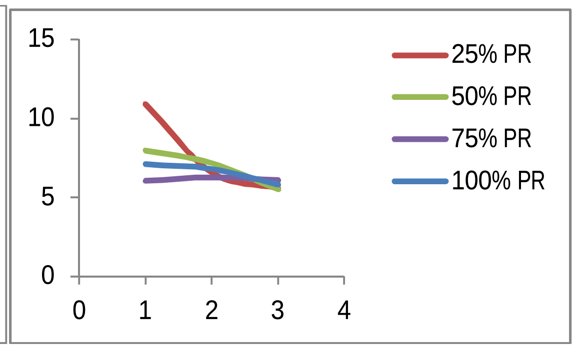

Fig.6

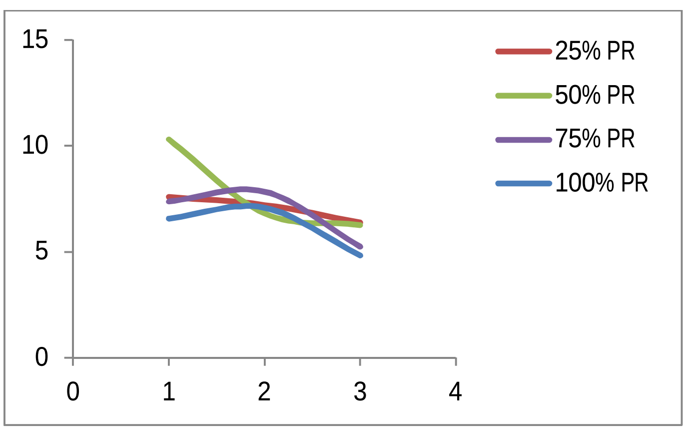

Fig.7

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In the fourth experiment, as shown in (Fig.5) the maximum damping is found for 100% PR with cavity size 24 mm diameter and height 47 mm. the minimum damping is found for 25% PR with cavity size 32 mm diameter and height 56 mm. Here, 24 mm diameter and height 47 mm with 100% PR is effective. In which energy loss due to friction in between ball to ball and ball to cavity is found more. In the fifth experiment, as shown in (Fig.6) the maximum damping is found for 50% PR with cavity size 32 mm diameter and height 56 mm. the minimum damping is found for 25% PR with cavity size 24 mm diameter and height 37 mm. Here, 32 mm diameter and height 56 mm with 50% PR is effective. In which energy loss due to friction in between ball to ball and ball to cavity is found more. In the sixth experiment, as shown in (Fig.7) the maximum damping is found for 100% PR with cavity size 32 mm diameter and height 56 mm. the minimum damping is found for 50% PR with cavity size 24 mm diameter and height 37 mm. Here, 32 mm diameter and height 56 mm with 100% PR is effective. In which energy loss due to friction in between ball to ball and ball cavity is found more.

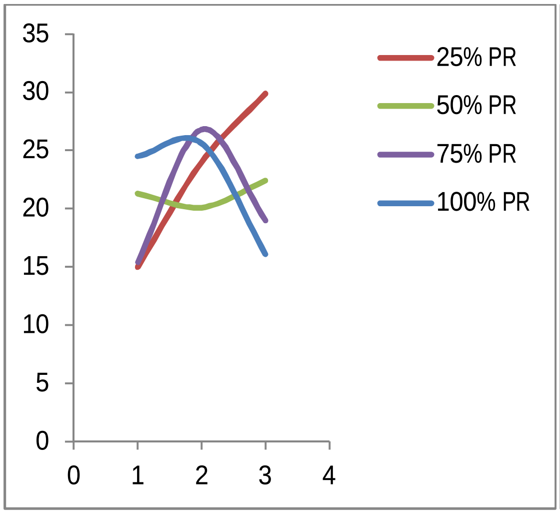

Fig.8

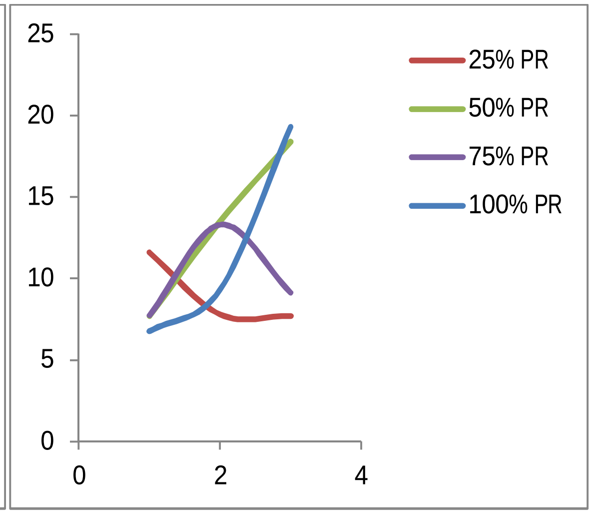

Fig.9

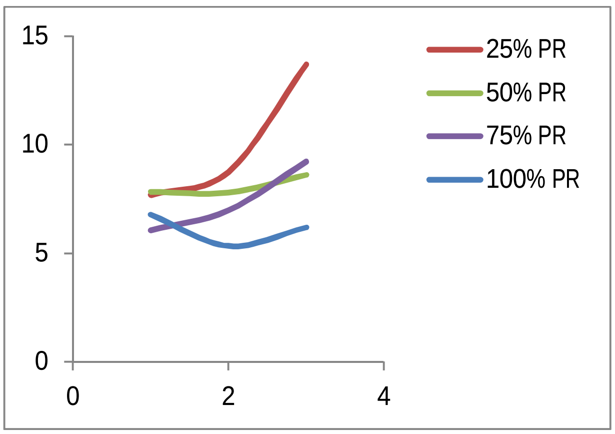

Fig.10

In the seventh experiment, as shown in (Fig.8) the maximum damping is found for 25% PR with cavity size 24 mm diameter and height 37 mm. the minimum damping is found for 25% PR with cavity size 32 mm diameter and height 56 mm. Here, 24 mm diameter and height 37 mm with 25% PR is effective. In which energy loss due to impact is found more. In the eighth experiment, as shown in (Fig.9) the maximum damping is found for 100% PR with cavity size 24 mm diameter and height 37 mm. the minimum damping is found for 100% PR with cavity size 32 mm diameter and height 56 mm. Here, 24 mm diameter and height 37 mm with 100% PR is effective. In which energy loss due to friction in between ball to ball and ball to cavity is found more. In the ninth experiment, as shown in (Fig.10) the maximum damping is found for 100% PR with cavity size 24 mm diameter and height 47 mm. the minimum damping is found for 25% PR with cavity size 32 mm diameter and height 56 mm. Here, 24 mm diameter and height 47 mm with 100% PR is effective. In which energy loss due to friction in between ball to ball and ball to cavity is found more.

VI. CONCLUSIONS

For ball size 4 mm, mild steel for 25% PR with cavity size 24 mm diameter and height 37 mm, 50% PR with cavity size 24 mm diameter and height 37 mm, 75% PR with cavity size 24 mm diameter and height 37 mm and for 100% PR with cavity size 24 mm diameter and height 37 mm is found effective. For ball size 4 mm, plastic for 25% PR with cavity size 24 mm diameter and height 47 mm, 50% PR with cavity size 32 mm diameter and height 56 mm, 75% PR with cavity size 32 mm diameter and height 56 mm, and for 100% PR with cavity size 24 mm diameter and height 37 mm is found effective. For ball size 4 mm, sand for 25% PR with cavity size 32 mm diameter and height 56 mm, 50% PR with cavity size 32 mm diameter and height 56 mm, 75% PR with cavity size 32 mm diameter and height 56 mm, and for 100% PR with cavity size 24 mm diameter and height 47 mm is found effective. For ball size 5 mm, mild steel for 25% PR with cavity size 24 mm diameter and height 37 mm, 50% PR with cavity size 32 mm diameter and height 56 mm, 75% PR with cavity size 32 mm diameter and height 56 mm, and for 100% PR with cavity size 24 mm diameter and height 47 mm is found effective. For ball size 5 mm, plastic for 25% PR with cavity size 32 mm diameter and height 56 mm, 50% PR with cavity size 32 mm diameter and height 56 mm, 75% PR with cavity size 24 mm diameter and height 37 mm, and for 100% PR with cavity size 32 mm diameter and height 56 mm is found effective. For ball size 5 mm, sand for 25% PR with cavity size 32 mm diameter and height 56 mm, 50% PR with cavity size 32 mm diameter and height 56 mm, 75% PR with cavity size 32 mm diameter and height 56 mm, and for 100% PR with cavity size 32 mm diameter and height 56 mm is found effective. For ball size 6 mm, mild steel for 25% PR with cavity size 24 mm diameter and height 37 mm, 50% PR with cavity size 24 mm diameter and height 47 mm, 75% PR with cavity size 24 mm diameter and height 37 mm, and for 100% PR with cavity size 32 mm diameter and height 56 mm is found effective. For ball size 6 mm, plastic for 25% PR with cavity size 32 mm diameter and height 56 mm, 50% PR with cavity size 24 mm diameter and height 37 mm, 75% PR with cavity size 24 mm diameter and height 37 mm, and for 100% PR with cavity size 24 mm diameter and height 37 mm is found effective. For ball size 6 mm, sand for 25% PR with cavity size 24 mm diameter and height 37 mm, 50% PR with cavity size 24 mm diameter and height 47 mm, 75% PR with cavity size 24 mm diameter and height 37 mm, and for 100% PR with cavity size 24 mm diameter and height 47 mm is found effective. From all this result we get for ball size 4 mm and mild steel material with 24 mm diameter and height 37 mm with 50% PR is found most effective.

VII. ACKNOWLEDGMENT

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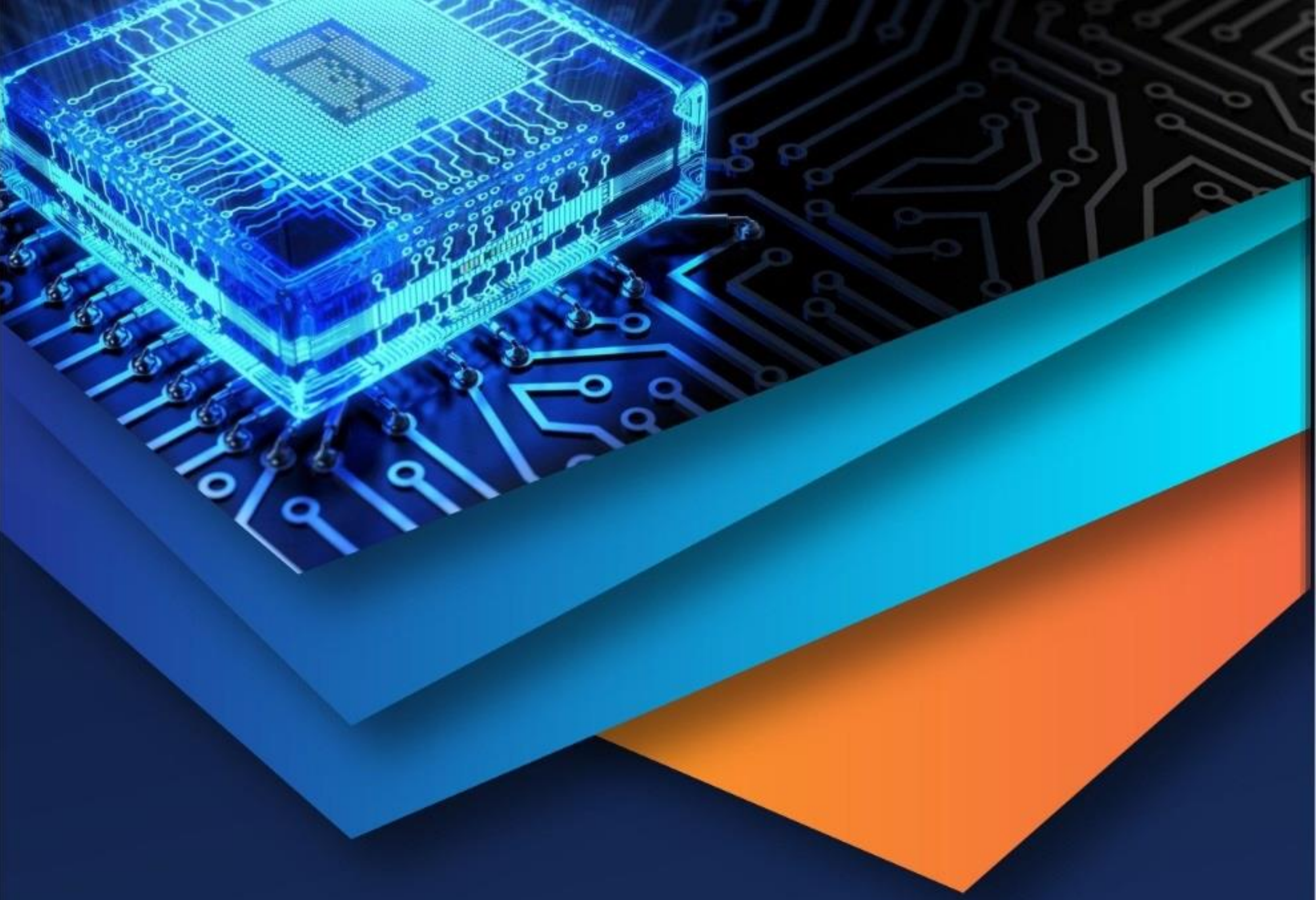

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