Design and Development Of Particle Damper For Rock Breaker Handle For Vibration Mitigation

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***Abstract*—Hand transmitted vibration (HTV) is one of the most common hazards faced by workplaces. A major source of HTV is hand held tools, such as pneumatically driven chipping hammers and rock drills. The issue of human comfort when faced with machine interaction has acquired a lot of interest in the recent years. Minimization of the level of vibration in such tools is the key requirement. Damping is the resistance to the motion of the vibrating body, which causes a vibrating body to come to rest or equilibrium position. Active damping and passive damping are most widely used methods for vibration mitigation. Active damping techniques cannot be used in all conditions due to, for example, cost, environment, power requirements, etc. In this conditions, passive damping techniques are a most likely alternative method used. Particle damping ,in which particles are moved freely to produce damping effect in a cavity. In this paper effort has been made to find solution for the above mentioned problem using particle damper. Handle of the rock breaker existing cavity already, with the help of DOE WE define how many times experimentation carried out, according to that we perform experimentation test, for more accuracy purpose we taken reading twice and also develop mathematical model on Minitab 17. in this paper we find out optimum factors for vibration mitigation.**

I. INTRODUCTION

A.HAND-ARM VIBRATION IN CASE OF ROCK DRILL

Vibration exposure from regular work with powered hand-held tools, equipment or processes can have adverse effects on the hands and arms of users operating the machine. Vibrations are generated because body oscillates due to internal and external forces act on it (refer Fig. 1). In hand-arm vibration, the surface of a work piece or the handle of a machine vibrates rapidly, due to this motion is transmitted into the arm and hand. For hand-arm vibration, the important range of frequencies is from about 8 Hz to 1000 Hz. Therefore, the risk of damage to the body is not equal at all frequencies. The frequency-weighting is used to represent the damage from different frequencies. Hence, the weighted acceleration decreases due to increase in the frequency. For hand-arm vibration, the single frequency-weighting curve is used for all three axes. From each vibration axis a frequency-weighted root-mean-square average acceleration is determined. Refer table for vibration total values of some common hand-held power tools. The vibration exposure, of a worker over a working day depends on the duration of exposure to vibrations as well as the vibration magnitude at the gripped surface(s) often on the tool(s) used.

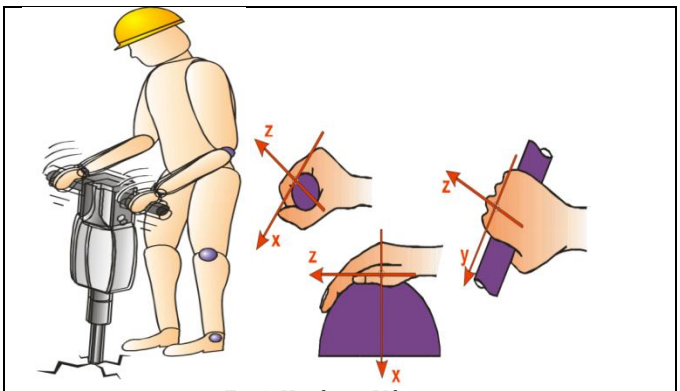

Fig 1: Hand-arm Vibration

Table1 : Vibration Values of Some Common Hand-Held Power Tools

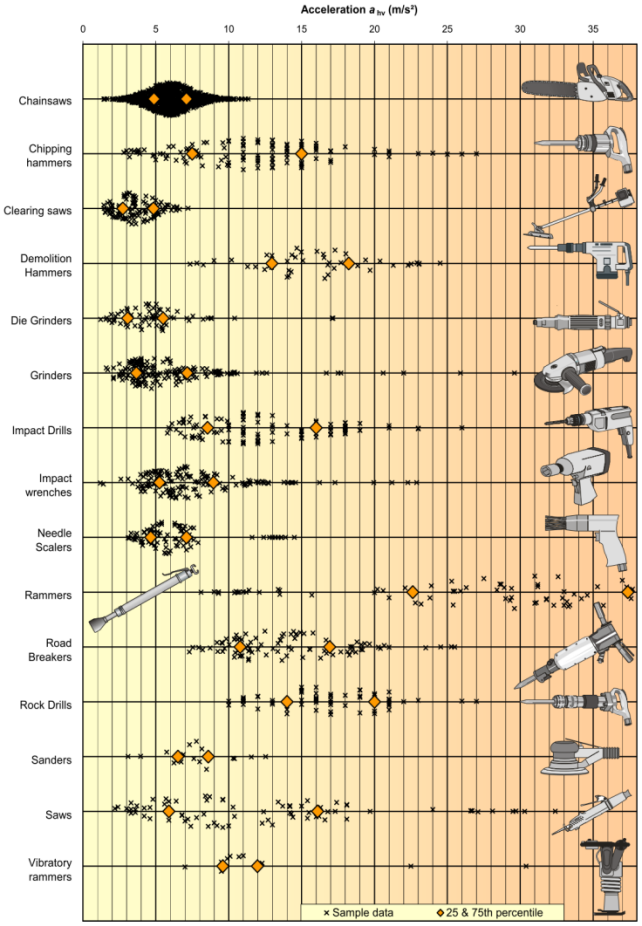

chart shows various vibration levels in various power tools to prevent vibration for human comfort, demand raise to reduce vibration. for control vibration various techniques. For experimentation purpose we use handle of medium duty breaker, these machines are designed to operate most efficiently as a demolition tool for a variety of applications.

Fig 2- Hand rock breaker.

B.VIBRATION REDUCTION TECHNIQUES

Active damping and passive damping are most widely used methods for vibration mitigation. Active damping techniques cannot be used in all conditions due to, for example, cost, environment, power requirements, etc. In this conditions, damping(Passive) techniques are a most likely alternative method used. Passive damping techniques include viscous damping, visco-elastic damping, friction damping and impact damping. Due to the above limitations, awareness is given on impact dampers, mainly for use in cryogenic environments or at elevated temperatures.

Particle damping is the process in which particles are moving freely in a cavity to produce a damping effect. In particle dampers, small to medium sized particles are placed inside a structure subjected to dynamic forces. Upon external excitations, the structure vibrates such that the particles inside exchange momentum through inelastic collisions. Also, in this process, the particles collides each other and the walls of the closed cavities to dissipate energy in the form of heat. Particle damping can be conducted at high temperatures where other forms of passive damping cannot be conducted..

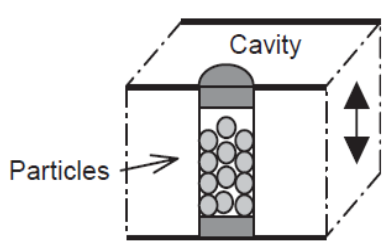

Fig 3. A schematic diagram of a particle damper.

C.PROBLEM DEFINATION

Hand-arm vibrations are very serious in evaluation of human performance. Human performance drastically deteriorates wherever it is exposed to vibration. Handles are the medium of connection between man-machine interactions. Mitigation of the vibrations introduced at the handle is the key issue in any machine or device. It is seen that the handles posses inherent cavity, which is desirable for installing the particle damper.

D. Literature Review

Steven E. Olson et al. [7] established an analytical particle damping model. They did an analytical evaluation of the particle damper. They 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 within the individual particles and the cavity walls are been calculated based on force–dislocation relations. Application of the model has been studied by testing the cantilever beam.

Zhiwei Xu,et. al.[9] The purpose of this paper was to find an function of particle damping technique for doing the clatter decline of a desk-top industrial machine. Particle damping is a technique of bit particles are used for damping embedded within small holes in a vibrating structure

Pranali Khatake et al. [10] introduced a vibration attenuation technique for boring bar through the implementation of passive damper. They 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..

E .Objectives

As per the discussion so far we need to design a passive damper using particle damping technique to minimize the level of vibration observed in case of rock-drill handle. In this work we are going to design and develop a particle damper which is best suitable for the applications subjected to hand-arm vibrations. Before finalizing the scheme of experiments we need to set our objectives first. Step by step objectives are listed below:

- To configure particle damper in rock-drill handle for minimisation of vibrations.
- To optimize the particle impact damper design parameters viz. particle size, packing ratio, particle material to achieve the above objective
- To test the developed particle damper under at different frequency and amplitude levels.

To develop the relation between particle size, packing ratio, particle material, frequency and amplitude with vibration acceleration

II.METHODOLOGY AND INPUT

A. Computation Of Natural Frequency Of Handle Of Rock Breaker

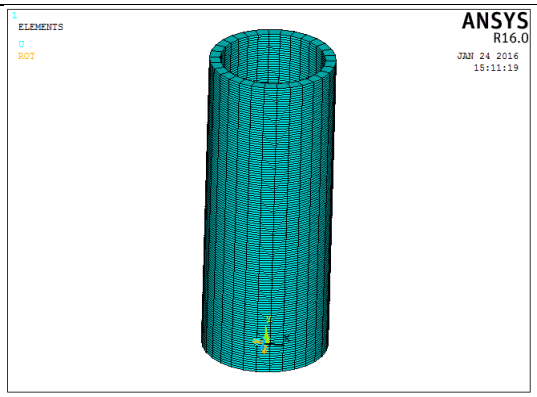

Figure 4.Modal analysis

Table 2- Natural Frequency

Load Step	Natural Frequency (Hz)
1	74.601
2	197.98
3	277.85
4	319.24
5	576.85
6	774.83
7	957.76

B. Design of Experiment (DOE)

Success of any research work depends on the proper planning and execution of the experiments. To logically analyze the data obtained after conduction of experiments, it is necessary to scientifically plan the number of experiments which are required to be carried out.

Parameters to be considered

- Particle size,
- Particle material,
- Packing Ratio,
- Excitation frequency,
- Excitation amplitude

Factors & its level

Table 3- Factors And level

Factor				Level		
		Sym-bol	Unit	1	2	3
A	Particle Size	d	mm	2	3	4
B	Particle Material	m		Steel	Poly-mer	Steel+Polymer
C	Packing Ratio	v	%	25	50	100
D	Excitation Frequency	N	rpm	300	600	1200
E	Excitation Amplitude	a	mm	1	1.5	2

(DOE) Technique: This most widely used technique ensures valid and unbiased conclusions. DOE methods like response to surface methodology, factorial design and Taguchi methods are now most widely used in place of one factor at a time, rather than experimental approach which is time consuming and more costly. The knowledge of having the contribution of individual control variable in most of the manufacturing process is important in deciding the nature of control to be administered during operation. Based on the various numerical analysis methods studied, the technique of defining and investigating all possible conditions in an experiment involving multiple factors is known as the Design of Experiments. There are two types of DOE which are widely used i.e. Factorial design & Taguchi method.

Total 5 numbers of parameters are finalized for conducting experiments to identify their role in minimizing the vibration level of handle of hand-rock breaker using particle damping. Normalized priority weights of each factor are determined. The percentage weight of each factor is calculated and based on the results, rank is decided for each individual factors. This rank will now help to prioritize the factors to be used for experimentation. 5 parameters are finalized according to their ranks for consideration for experimentation. A well known Taguchi approach is used only to decide the number of experiments to be carried out. 5 parameters with their 3 levels are finalized levels. of orthogonal array. Actor and level combination L_{27} orthogonal array is suitable.

III. DESIGN AND DEVELOPMENT OF EXPERIMENTAL SETUP

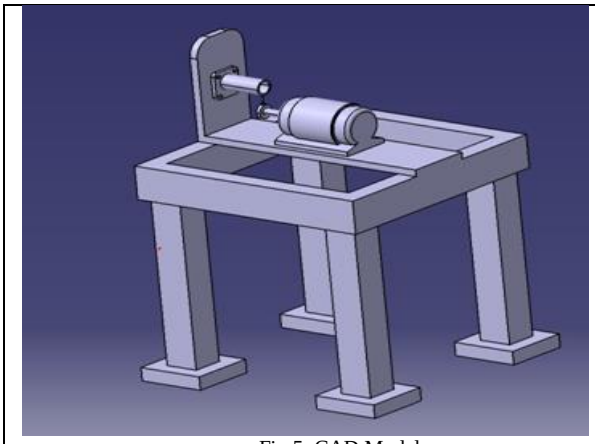

Fig 5. CAD Model

A. Solid model of experimental setup

Solid model of experimental setup designed in Catia V5, R20 version. Solid model contain all necessity features according to actual experimental setup.

It contain following components which assembled in this model.

Frontal frame of experimental setup, support of frontal frame (4 pillars), Motor 1/2 hp, support for specimen for fixed one end, circular plate with adjustable nut and bolt, specimen.

1. In figure 5. shows bare handle of hand rock breaker which, this is specimen which testing on experimental setup which shown in earlier cad model of experimentation.
2. In figure 6. shows actual specimen which carried out for experimental testing with the help of design of experiments.

Finally calculate the result with the help of FFT analyzer

Fig 6. complete handle of hand-rock breaker (Specimen)

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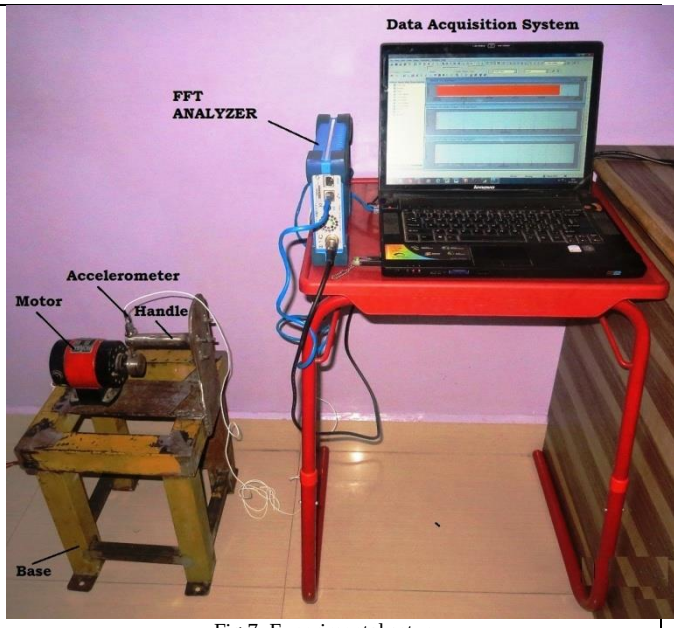

Fig 7. Experimental setup

B. Development of experimental setup

Frontal frame of experimental setup dimension 300mm x 300mm hollow square .four parts 300 mm cutting with the help of grinder and then join with the help of welding. Support of frontal frame (4 pillars) which dimensions 300 mm length all four pillars. In diagram shown development of setup which is fabricated according to specific dimension.

C. Theory of FFT Analyzer.

Fourier transform is a mathematical procedure to obtain the spectrum of a given signal. a signal which represented by an equation or a graph or a set of data points with time as an independent variable is transformed into another equation or graph or a set of data points where frequency is the independent variable, by using Fourier transform. A mathematical set of data points can be converted to a spectrum using Fourier transformation programmed in a digital computer. thus, this method to obtain the spectrum using computer is called as fast Fourier transform (FFT).consider the acceleration time plot of a machine structure that is subjected to the excessive vibrations, from this plot, it is very difficult to identify the cause of vibrations. if the acceleration-time plot is transformed into the acceleration-frequency plot the resulting frequency is shown .the instrument which converts the input signal, with time as an independent variable, into frequency spectrum and displays it in graphical is called as spectrum analyzer or FFT analyzer. such analyzer receives analog voltage (i.e. displacement, velocity, acceleration) from an amplifier through the filter for computations. the analyzed signals, in numerical or graphical form, can be used to find the natural frequencies we are using FFT Model OR 34, OROS four channel real-time multi analyzer for experimentation purpose and compute result.

D. FFT Analyzer

Figure shows the FFT Analyzer used to measure the frequency response of the PI damper in terms of frequency vs. acceleration. This is a 4-channel FFT Analyzer of OROS make and model is OR-34.

Fig 8: FFT Analyzer (OROS OR34)

The device is used for common aural and vibration measurements, occupational health monitoring, environmental monitoring and safety monitoring. Features of OR34 – 2, 4 channels compact analyzer include

- AC/DC power supply
- Real-time bandwidth 40 kHz
- 2 external triggers/tachometers inputs

Accelerometer

Dytran make 3056 B2 D accelerometer which is used to measure acceleration from the interaction zone of work piece and boring tool.

Fig 9:Dytran 3056 B2 D accelerometer

The Model 3056 B2 shown is a magnetic mount accelerometer. Features of Dytran 3056 B2 D accelerometer are;

- Weight, 10 grams
- Material, base, cap & connector titanium
- Operating range, -55 to +120°C
- Frequency range, 1 to 10,000 Hz
- Sensitivity, 100mV/g

Fig 10.various sizes steel particles


Fig 11.various sizes of polymer particles

IV .RESULT AND DISCUSSION

A. Result table of experimental test

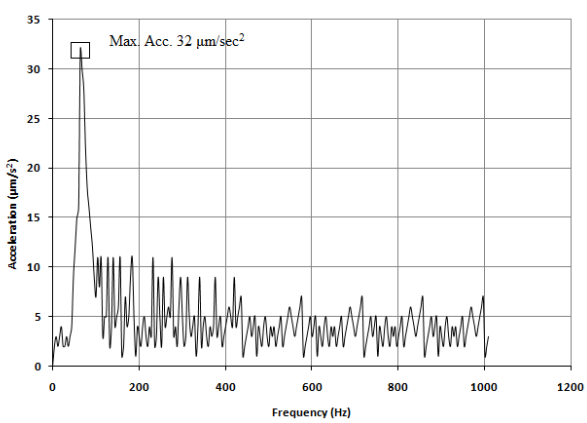

Fig 12. Frequency Response Curve

frequency response curve of expeiment test no-24.Frequency response curve it is seen that peak response of the system
32 µm/sec^2 .

Table 4 Experimental test results

Test No.	Coded Variables					Vibration Amplitude (µm/sec^2)	
	A	B	C	D	E	Y_1	Y_2
1	1	1	1	1	1	12	11
2	1	1	1	1	2	12	11
3	1	1	1	1	3	16	18
4	1	2	2	2	1	16	17
5	1	2	2	2	2	20	21
6	1	2	2	2	3	24	23
7	1	3	3	3	1	78	77
8	1	3	3	3	2	81	79
9	1	3	3	3	3	92	90.8
10	2	1	2	3	1	54	52
11	2	1	2	3	2	14	14
12	2	1	2	3	3	89	88
13	2	2	3	1	1	54	52
14	2	2	3	1	2	58	59
15	2	2	3	1	3	71	72
16	2	3	1	2	1	24	21
17	2	3	1	2	2	27	27
18	2	3	1	2	3	47	49
19	3	1	3	2	1	23	24
20	3	1	3	2	2	48	47
21	3	1	3	2	3	56	57
22	3	2	1	3	1	12	12
23	3	2	1	3	2	12	11
24	3	2	1	3	3	32	34
25	3	3	2	1	1	24	23
26	3	3	2	1	2	34	33
27	3	3	2	1	3	47	48

B. S/N Ratio Smaller Is Better Criteria

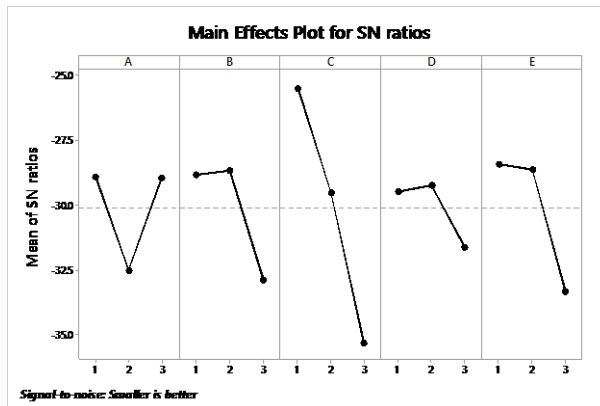

Fig 13 - Plot of SN ratio

The above graph shows SN Ratio plot . With increasing the S/N ratio, the loss linked with it can be minimized. The S/N ratio determines the set of operating conditions from variation within the results.

The function of this work is minimization. The S/N ratio defined according to the Taguchi method is as follows

$$S/N = -10 \text{ Log } \frac{1}{n} \sum_1^n Y_i^2$$

Where,
S/N = observed value (unit=dB).
Yi = characteristic value.
i and n = the number of observations or number of repetitions in a trial. The smaller the ratio of signal-to-noise (S/N), the better is the criteria which concludes that A1, B2, C1, D2, E1 is optimum combination for vibration mitigation.

C. Interaction plot

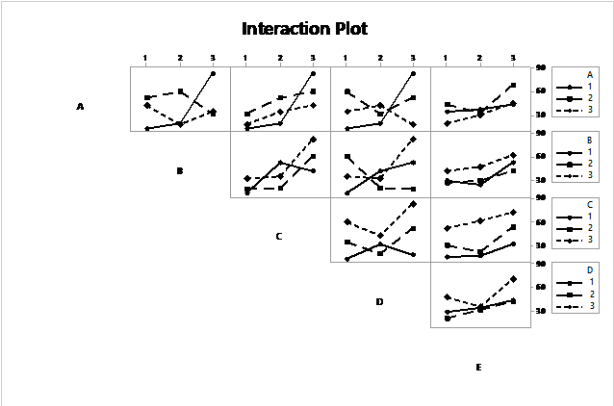

Fig 14 - Interaction plot

D. 3D Surface Plot

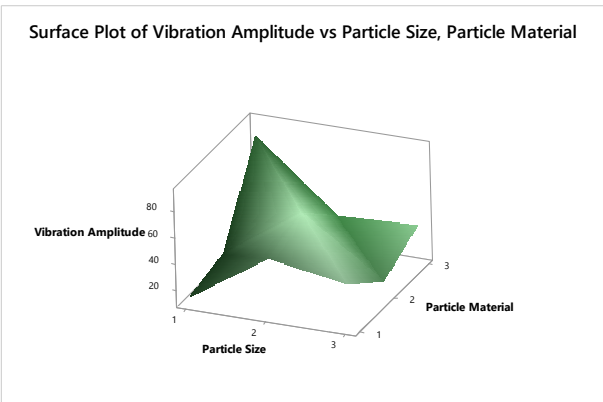

Fig 15 - 3D surface plot

3D surface plot it is again verified that the particle size should be 1 mm and particle material must be polymer so that the vibration level minimum.

E. ANOVA

Table 5 - Table of ANOVA

Factor	DoF	SS	MS	F	P-value
A	1	192.1	192.1	8.97	0.000
B	1	879.2	879.2	0.76	0.394
C	1	7352.8	7352.8	3.46	0.077
D	1	950.5	950.5	28.93	0.000
E	1	2022.5	2022.5	3.74	0.067
e	21	5336.5	254.1	7.96	0.010

Analysis of variance (ANOVA) is a statistical method which plays important role analyze the differences between group means and their related events.

F. Multiple Linear Regression Analysis

Regression Analysis is a very efficient method for investigating functional relationships between the variables..

Regression Equation

Vibration Amplitude = -43.9 - 3.27 A + 6.99 B + 20.21 C + 7.27 D + 10.60 E

R^2 = 78%

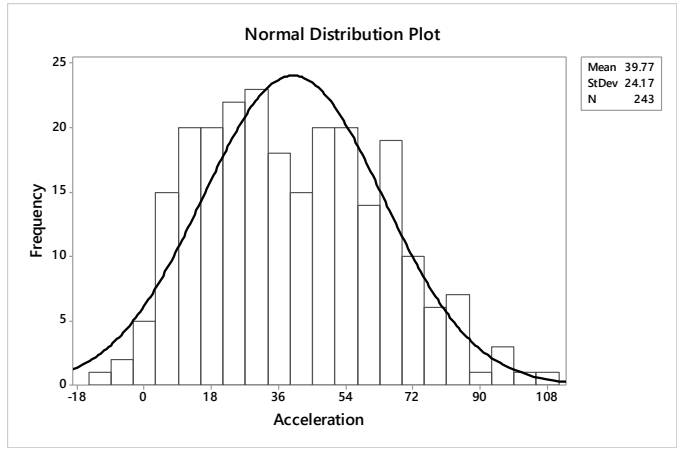

Fig 16 - Normal Distribution Plot for Full Factorial Results

V .CONCLUSION

- Signal-to-noise (S/N) smaller is better criteria it concludes that A1, B2, C1, D2, E1 is optimum combination for vibration mitigation.
- From interaction plot it is observed that there is strong interaction between all the factors.
- 3d surface plot it is again verified that the particle size should be 1 mm and particle material must be polymer so that the vibration level minimum.
- From ANOVA plot it concludes that factor B is significant for vibration reduction.

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