



RESEARCH ARTICLE

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EXPERIMENTAL VALIDATION OF VIBRO SEPARATOR AND ANOVA TECHNIQUE FOR AMPLITUDE

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ABSTRACT

Over 60% of India's gross domestic product (GDP) is attributed to the agricultural sector. Advancements in mechanical and instrumentation technologies have significantly improved research and development in agricultural machinery. Vibration analysis plays a critical role in predictive maintenance by allowing engineers to detect potential issues in machinery before they lead to system failures. One important factor in vibration analysis is amplitude, which helps us understand how severe the vibrations are and whether there might be any mechanical issues. Amplitude is usually measured in terms of displacement (like micrometers or mils), velocity (millimeters per second or inches per second), or acceleration (g or millimeters per second squared). It's directly connected to the amount of mechanical stress the equipment is experiencing. In this study, we used analysis of variance (ANOVA) to design experiments, create a regression model, and run tests that looked at how the vibro motor's angle, its rotational speed, and the material's modulus of elasticity all work together to affect amplitude. We then optimized these factors to improve the vibro separator's flow rate performance



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I. INTRODUCTION

Having a well-planned experimental design is key to successfully developing products and processes. It starts with a solid understanding of the system you're studying. In factorial designs, both the input (independent) and output (dependent) variables are carefully tested. After identifying the important factors, experiments are set up and analysed to find the best combination that gives the most favourable result. Optimization is at the heart of this process, aiming to choose the best possible outcome from several options. One popular approach to optimization is Response Surface Methodology (RSM) [1], [2]. This technique is widely used to design experiments, analyze data, and improve products or processes. RSM combines statistical and mathematical tools to build models and find the best operating conditions within a given range. It works especially well when multiple variables affect how a system performs. By using polynomial regression models, RSM helps us understand how the inputs relate to the outputs, allowing for fine-tuning of parameters and accurate prediction of results. This method also helps create reliable predictive models, makes experiments more repeatable, and supports ongoing process improvement. In today's industrial world, machines play a vital role in keeping operations running smoothly [3]. That's why regular and effective machine monitoring is essential—unexpected breakdowns can lead to significant financial losses for businesses. Litak and Friswell investigated the dynamics of gear systems, focusing on how irregularities and flaws in gear tooth geometry affect system stiffness. Ramchandra proposed several diagnostic approaches and concluded that the Shock Pulse Method (SPM) is effective in assessing machine condition, offering a cost-efficient alternative to replacement [4], [5]. Mantari, J. L., & Monge, J. C. comprehensive analytical study of buckling, free vibration, and bending behaviours of functionally graded (FG) sandwich plates subjected to mechanical loads [6] In a recent publication, the effort to forecast the optimal solutions for the amplitude value which ultimately utilised to enhance flow rate of the system.

II. COMPUTATIONAL MODEL AND DATA ANALYSIS

The core parts of a reciprocating vibro separator are the motor, which powers the machine; a connecting plate and rubber pads, which join the parts and absorb vibrations; a separator box to hold the materials; and an unbalanced mass that creates the shaking motion. These components are designed using parametric software and evaluated through a CAE program, as illustrated in figure 1(a). The parametric software is employed to develop the parts along with their respective dimensions. [7-10]

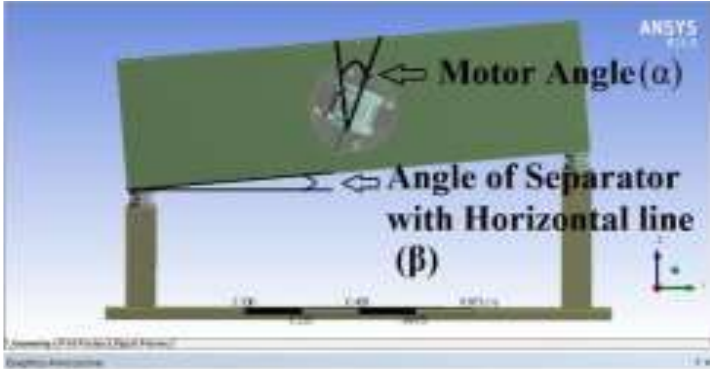


Figure 1(a): Indication of different angle
Source: Authors, (2026).

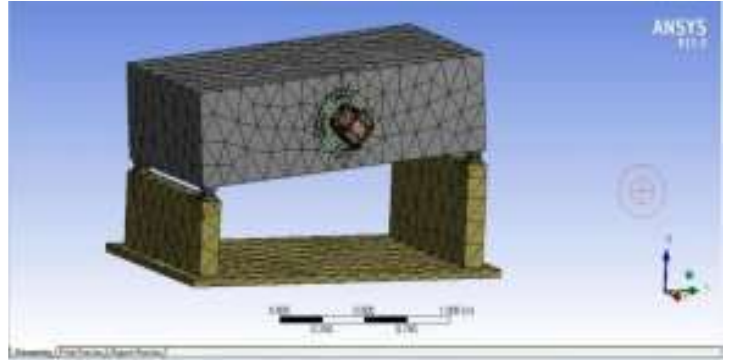


Figure 1(b): parametric model of vibro separator
Source: Authors, (2026).

The tetrahedral mesh type, as illustrated in figure 1(b), is employed for analytical purposes. The coarse mesh generation adopts a manually specified size of 120 mm for the separator box, while a default size is applied to the other sections. In total, the setup comprises 27,840 mesh elements, with 2,347 elements specifically in the foundation rubber. The mesh size of the box was increased from the default to minimize complexity and reduce the number of nodes, potentially accelerating the resolution process. The device features a total of 10 nodes. The connecting plate configuration analysed by the CAE tool is constructed from mild steel [11]. For the plates and separator boxes in our analysis, structural steel material is presumed to be utilized. The model has been validated against a computational model to collect further data for optimization purposes. The experimental work is conducted at GAJANAND Industries located in UNJHA. In this setup, the separator box features two motors attached to the side walls at the midpoint of the box's height. Each motor is connected to four unbalanced masses, each weighing 3.34 kg. A specialized sensor of the piezoelectric pickup type is utilized, functioning within a frequency spectrum of 1-10 kHz. The sensor with sensitivity of 107 mV/(m/s²), and it employs an integral electronics piezoelectric accelerometer (IEPE) input mode. The CoCo-analyser, manufactured by Crystal Instruments, is a device used for measuring and analysing vibration and other dynamic signals, including acceleration data as shown in figure 2 [12]. As shown in figure 3(a),3(b),3(c) taking the various amplitude data by changing the modulus of elasticity (10MPa,25MPa,40MPa) for rubber pad with 1100rpm.comparing the experimental data with computational data as shown in table 1, we assume that the experimental amplitude value is nearer to the computational value.



Figure 2: Experimental set up
Source: Authors, (2026).

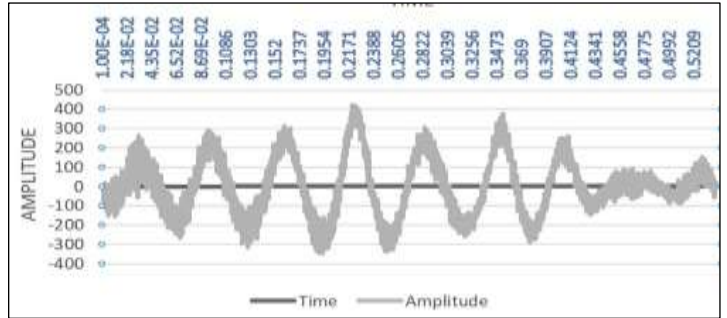


Figure 3 (a): TIME V/S AMPLITUDE at 25MPa
Source: Authors, (2026).

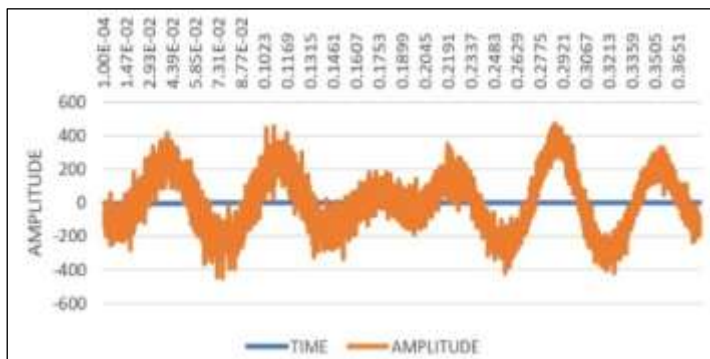


Figure 3 (b): TIME V/S AMPLITUDE @ 10 Mpa
Source: Authors, (2026).

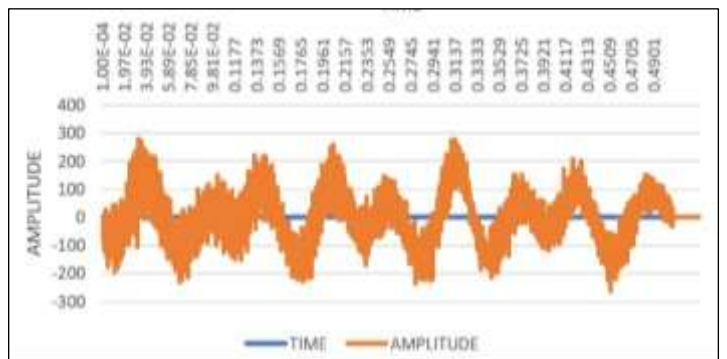


Figure 3 (c): TIME V/S AMPLITUDE @ 40 Mpa
Source: Authors, (2026).

Computational model was verified using experimental data hence starting the computational data acquisition and altering the various number of design parameters like angle (28⁰:30⁰:32⁰), speed (900,1100,1300), and modulus of elasticity (10MPa,25MPa,40MPa) was completed for getting amplitude value and process with the RSM method to achieve best optimised value of amplitude to achieve better flow rate.

Table :1 Computational Data.

Motor Angle (Degrees)	Modulus of Elasticity (Mpa)	Motor speed (RPM)	Amplitude mm/Sec ²
30	10	1100	400
	25	1100	415
	40	1100	293

Source: Authors, (2026).

III. SYSTEM ANALYSIS THROUGH RESPONSE SURFACE MODEL (RSM)

A practical and efficient approach to analyze the experimental study focused on statistical models of vibration responses in a vibro separator through Response Surface Methodology (RSM) is a specific form of factorial design. The RSM technique is employed to find the optimal solution for the amplitude by identifying viable solutions. To assess the simultaneous impacts of variables such as speed, motor angle, and the Modulus of Elasticity of rubber on amplitude, multiple trials are performed utilizing the ANOVA method. [3], [13]. The RSM was utilized in this study to execute the experimental design aimed at developing the regression model, as well as to conduct multiple trials to investigate the simultaneous effects of the parameters on amplitude.

Table 2: Design of Experiment Parameters.

Factor	Name	Units	Type	Subtype	Minimum	Maximum		
A	SPEED	RPM	Categorical	Nominal	900	1300	Levels:	3.00
B	ANGLE	DEGREE	Categorical	Nominal	28	32	Levels:	3.00
C	MODULUS OF ELASTICITY	MPa	Categorical	Nominal	10	40	Levels:	3.00
Responses:								
Response	Name	Units	Observations	Minimum	Maximum	Mean	Std. Dev.	Ratio
R1	Amplitude	mm/s ²	24.00	120	450	323.89	95.11	3.75

Source: Authors, (2026).

The RSM method with a quadratic design model was used in this study to develop 24 runs while taking into account the aforementioned design of experiment parameters. The minimum and maximum values of these parameters are shown in Table 2 along with the results' set as shown in Table3.

Table 3: Design of Experiment runs with responses.

Std	Run	A: SPEED	B: ANGLE	C: MODULUS OF ELASTICITY	amplitude
		RPM	DEGREE	MPa	mm/s ²
2	1	1100	28	10	200.5
8	2	1300	32	10	370
6	3	1300	30	10	350
7	4	900	32	10	160
3	5	1300	28	10	410
19	6	900	30	40	375
12	7	1100	30	25	415
5	8	1100	30	10	400
22	9	900	32	40	120
16	10	1300	32	25	400
14	11	900	32	25	150
20	12	1100	30	40	293
1	13	900	28	10	375
23	14	1100	32	40	210
4	15	900	30	10	375
15	16	1100	32	25	300
11	17	1300	28	25	411.79
10	18	1100	28	25	310
18	19	1100	28	40	300
9	20	900	28	25	450
13	21	1300	30	25	312
17	22	900	28	40	366
24	23	1300	32	40	440
21	24	1300	30	40	280

Source: Authors, (2026).

IV. RESULTS AND DISCUSSION

In this research, input parameters such as Angle, Speed, Modulus of Elasticity, and their corresponding response in the form of Amplitude have been documented and presented in Table no.3. The Model F-value of 5.40 indicates that the model is significant. There exists only a 3.54% probability that an F-value of this magnitude could arise from random noise. P-values that are less than 0.0500 suggest that the model terms are significant. In this instance, Speed, Angle, and the combined effect of Speed and Angle have a greater impact on Amplitude. Therefore, Speed (A), Angle (B), and the combined effect of Speed and Angle (AB) are all significant model terms, indicating that they are influential parameters.

Table: 4 ANOVA for Quadratic Model.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	1.979E+05	18	10993.33	5.40	0.0354	significant
A-SPEED	31347.62	2	15673.81	7.70	0.0297	
B-ANGLE	42953.77	2	21476.89	10.56	0.0160	
C-MODULUS OF ELASTICITY	7573.76	2	3786.88	1.86	0.2488	
AB	1.091E+05	4	27280.46	13.41	0.0070	
AC	6394.16	4	1598.54	0.7858	0.5805	
BC	7669.00	4	1917.25	0.9424	0.5092	
Residual	10172.01	5	2034.40			
Cor Total	2.081E+05	23				

Source: Authors, (2026).

The factors were encoded using a specified coding scheme. The sum of squares was calculated using the Type II classical method. The model's F-value is 5.40, indicating that the model is statistically significant at the 3.54% significance level. This means there is only a 3.54% probability that an F-value this large could have occurred due to random chance or noise. Individual model terms with p-values less than 0.05 are considered significant, as is the case with factors A, B, and their interaction AB. Conversely, terms with p-values greater than 0.10 are deemed not significant. If the model contains many such insignificant terms—excluding those necessary to maintain model hierarchy—it may be beneficial to perform model reduction to improve model accuracy and interpretability. Figure 4 indicate that linearity is maintained hence the various values of amplitude for various runs is accurate and there is strong correlation between its actual and model's predicted values.

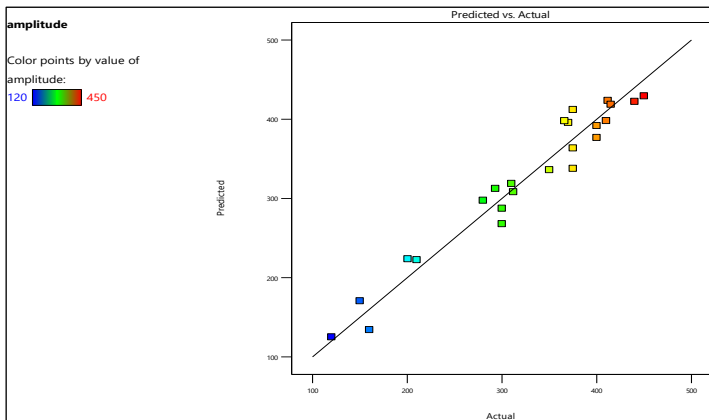


Figure 4: actual v/s predicted Graph
Source: Authors, (2026).

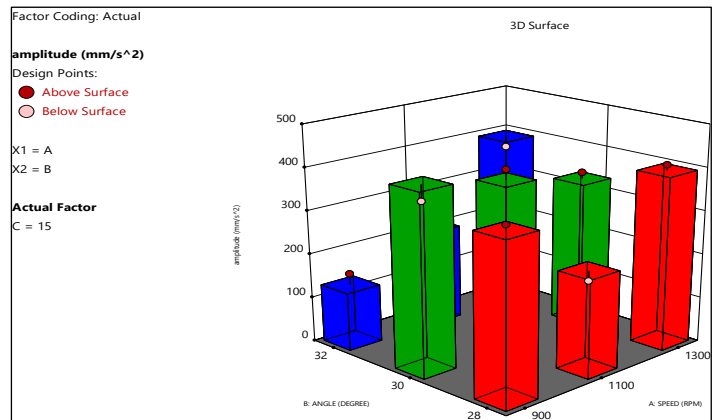


Figure 5: Speed v/s angle v/s amplitude
Source: Authors, (2026).

Figure:5 indicates that two parameters are more effective and the amplitude are achieved at 280 at 900 and 1300 RPM but at same time its reduced at 1100 RPM also for 300 values of amplitude decreases with increase in rpm.for 320 the value of amplitude increases with increase in rpm.

V. CONCLUSION

In the current study, the computational model has been validated against industrial data pertaining to the horizontal vibro separator. Using computational data, we can develop statistical models. The three-way interactions among various input factors, including Motor Angle, Speed, and modulus of elasticity, are analysed through ANOVA and the Response Surface Method, considering their individual and combined effects on amplitude, which is an output parameter, across all trials. The results of the survey lead to the following:

At 25 Mpa Modulus of elasticity the best solution is at 320 1300 RPM and 280 at 1100RPM and 900 RPM both.

VI. AUTHOR'S CONTRIBUTION

- Conceptualization:** Pavan M Bhatt, Dr D H Pandya
- Methodology:** Pavan M Bhatt.
- Investigation:** Pavan M Bhatt.
- Discussion of results:** Pavan M Bhatt, Dr D H Pandya

Writing – Original Draft: Pavan M Bhatt,
Writing – Review and Editing: Dr D H Pandya
Resources: Pavan M Bhatt,
Supervision: Dr D H Pandya
Approval of the final text: Pavan M Bhatt, Dr D H Pandya

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