Journal of
Data Acquisition and Processing

ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7546568

NONLINEAR DYNAMIC MOTION AND FLOW RATE ANALYSIS OF VIBRO SEPARATOR WITH EXPERIMENTAL VALIDATION FOR AGRICULTURE PROCESS INDUSTRY.

Pavan M. Bhatt[1], Nayana Gandhi[2], Divyang H. Pandya[3]

1.Research Scholar, Department of Mechanical Engineering- KSV University, Gandhinagar Gujarat, India

2.Assistant professor, Design Department, GUJARAT UNIVERSITY, Ahmedabad, Gujarat, India

3.Professor, LDRP Institute of Technology and Research, Gandhinagar, Gujarat, India.

Abstract:

In this paper, dynamic motion analysis of reciprocating vibro separator has performed to optimize working parameters. In present paper, effect of Motor angle and speed of motor has analysed to identified flow rate of vibro separator. CAD model of vibro-separator developed using parametric software and analyse with CAE tool for three different motor angle and three different speeds for the dynamic motion analysis of vibro separator. Dynamic motion analyses have carried out with Different motor angle 28^0,30^0,32^0 and motor speed at 1000 RPM. TDR (Time displacement response), FFT and Poincaré maps have utilized to identify dynamic motion such as periodic motion, quasi periodic, multi periodic or chaotic motion of system. Live Experimental data were taken from an agriculture industry with uni-axial piezoelectric sensor with sensitivity of 1.02mv/(m/s^2) along with 4-channel vibration analyser. Computational analyses have validated with live industrial data, further parameter alteration have carried out on computational model. Outcome of present research has led to conclude that the most suitable motor angle with most suitable speed for horizontal vibro separator is 28^0 and 1050 rpm speed of motor.

Keywords: Dynamic Motion analysis, FFT, Vibro-separator, Poincaré, CAE, flow rate

Introduction:

In the present world technology is used to reduce the work and required to provide best solution to the industries. Vibro separator is the machine which is used to remove the impurities from the material with the maximum flow rate. Dynamic characteristic of vibro separator have critical influence of the system. Vibration absorption has been achieved with rubber dampers in industries. Rubber damping co-efficient is one of the significant areas of research. Lee and Youn [1] proposed optimization method to design the rubber elastic dampers considering the dynamic mechanical behaviour.

Guo *et al.* [2] established a dynamic model of a rubber isolator by superimposing hyper elastic, viscoelastic, and elastoplastic models, and predicted the correlation between the vibration isolator amplitude and frequency.

Recent paper emphasizes the work of Changing the Motor angle ((α), motor speed and keeping the other parameters constant to find the effects on the vibro separator. For this research work we compare the experimental data with the computational data by varying the Motor Angle(α), motor Speed.

In this research work computational model is created in Parametric Software. This computational modal is validated within existing industrial modal based on input parameter like, vibro motor angle(α), motor speed and Stiffness of rubber pad. Dynamic failure of this computational modal is checked for output parameter like, amplitude and dynamic motion behaviour, velocity acceleration.

After validation of model will change the Motor angle(α) and speed of the vibro separator and gathered the output data like amplitude, dynamic motion behaviour and flow rate.

2. Literature Review

Chuanbo Xu Mao-Ru Chi, Liangcheng Dai, and Zhaotuan Guo have analysed the effect of pressure & Temperature on spring material considering the static stiffness. In this work, the relationship between Young's modulus and temperature of rubber was evaluated and the quantitative relationship between them was established. As conclusion, convexity correction method was found more realistic as compare to ellipse approximation method to evaluate static stiffness of spring.

Dong Hailin, Liu Chusheng, Zhao Yuemin, Zhao Lala have studied the motion of screen and concluded that travel velocity of the particles during linear screening is the fastest. They conclude that elliptical motion has good Velocity and efficiency than other motions. Circular motion gives lowest velocity with high screen efficiency.

HE Xiao-Mei, LIU Chu-sheng have concluded more effective parameters to optimize position of vibro motor to improve efficiency of vibro screen. Researchers observed different types of motion behaviour out of that mainly discuss as linear, circular or elliptical were noted. Position of exciter or vibro motor on vibro screen with respect to it's centre og gravity position of vibro screen have been analysed. This work concluded optimise design of vibro screen to increase production rate without increasing power consumption.

Jianzhong Xiao, Xin Tong have investigated the effects vibro screen frequency and swing declination angle using DEM 3D simulations. Their work concluded that simulated data of vibro-screen out come improved with optimizing vibro screen frequency with corresponding declination angle. Researchers suggested few empirical formula by regression analysis as conclusive remark.

Liu Chusheng, Wang Hong, Zhao Yuemin, Zhao Lala, Dong Halin have investigated experimental relation to optimise angle between base line & separator box bottom layer line. Researchers had included inclination of discharge (IOD) & screen deck inclination (SDI) to get maximise output. Researched concluded banana screening is more effective when increment of SDI should maintain between 10^0 to 5^0 .

Researchers investigated optimised operating speed of vibro motor is 900 to 1100 RPM and separator box inclination with horizontal is 5^0. Monica Solding justified the above conclusion with the monte carlo simulation method for parameter optimization.

2. METHODOLOGY:

Computational Analysis:

3D CAD model of the reciprocating vibro separator modeled with Parametric Software as shown in Figure 1. The analysis is done on CAE Tool. The Main parts of Reciprocating Vibro separator are 1) vibro-motor 2) Connecting plate 3) Rubber pad 4) Separator box and 5) unbalanced mass. Overall tetrahedral shape type mesh used to analyze the model. meshing of model

The mesh used for Analysis purpose is called tetrahedral shape type Mesh. Coarse mesh size was kept of 120 mm for separator box and for remain part it's default. Box mesh was taken to analyses rubber pad in model which led to generate total 27840 elements for entire model & 2347 elements for model of rubber foundation. Real time boundary conditions were applied to perform random -vibration analysis. Total 10 nods taken to reduce proceeding time and closer approximation of result.

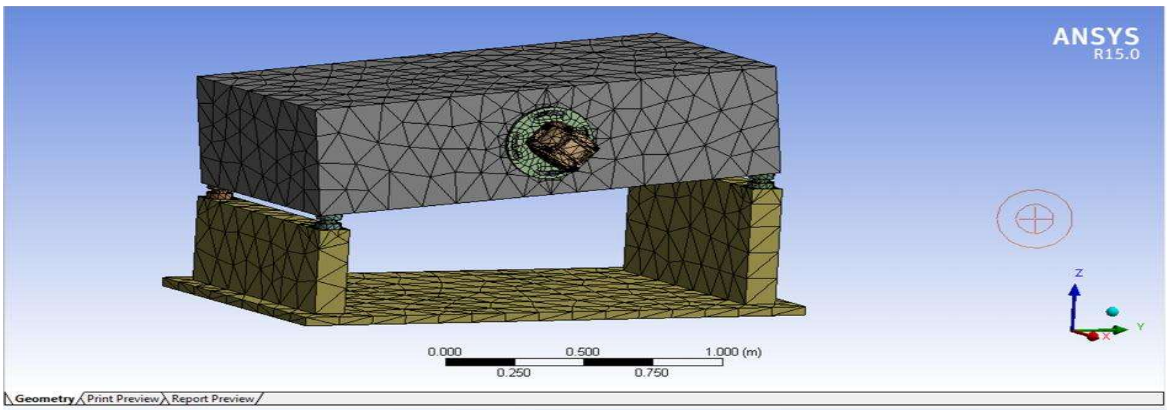

Figure 1 parametric model of vibro seperator

Table :1 Effective Parameters of Reciprocating Vibro Separator

Input Parameter	Output Parameter
Motor Angle (α)	Dynamic Motion Behavior
Motor Speed (RPM)	
Foundation Rubber Properties	Amplitude, Flow rate

In this research work, From **Table :1 Motor** angle (α), Motor speed (RPM) are considered as a varying input parameter. For this varying input parameter, the dynamic motion behaviour and amplitude, flow rate is observed for Reciprocating vibro separator.

EXPERIMENTAL ANALYSIS:

The experimental work carried out with 1000 rpm using two vibro motor on both side of separator. Vibro motor are having capacity of 0.5 HP with speed variation of 20 rpm. The experimental data acquisition did at GAJANAND industries in speed rang of 980 to 1020 rpm and motor angles of 30^0. Following Table:2 gives the detail specification of each part of experimental setup.

Table :2 Specification of reciprocating vibro separator

Component	Weight (Kg)	Material
Separator Box	505.63	Structural steel
Plate	6.37	Structural steel
Foundation Rubber	0.335	Rubber
Each Motor without Unbalanced mass	35.91	Gray cat iron

Figure :2 Experimental Setup

Horizontal reciprocating Vibro separator set up at Gajanand Industries, siddhapur Gujarat was utilized to collect real time data**. Two vibro motor attached on opposite side of separator wall as shown in fig.2. Each vibro motor had 2 unbalanced mass on each side of motor . Each unballanaced mass of 3.34 kg recorded.** Real time data collected at three positions on each side of separator as shown in fig.2. Uni-axial vibration sensor used which have special piezoelectric sensitivity of 1.02mv/(m/s^2). IEPE mode of input set to collect data in frequency range of 1-10 KHz. Real time data was analysed and available in user friendly data format for further research work.

RESULT AND DISCUSSION:

From below figure 2 of Poincare for experiment & computational graph, we conclude that the computational model having motor Angle (30^0), motor speed 1000±20 RPM,**100 N/mm Stiffness** is matching with experimental vibro separator. Hence computational model of vibro separator with motor Angle (30^0), motor speed 1000±20 RPM, foundation rubber **with 100N/mm Stiffness** has the same result as the Experiment.

Computational model Poincaré

with 100N/mm Stiffness **Experimental Poincaré**

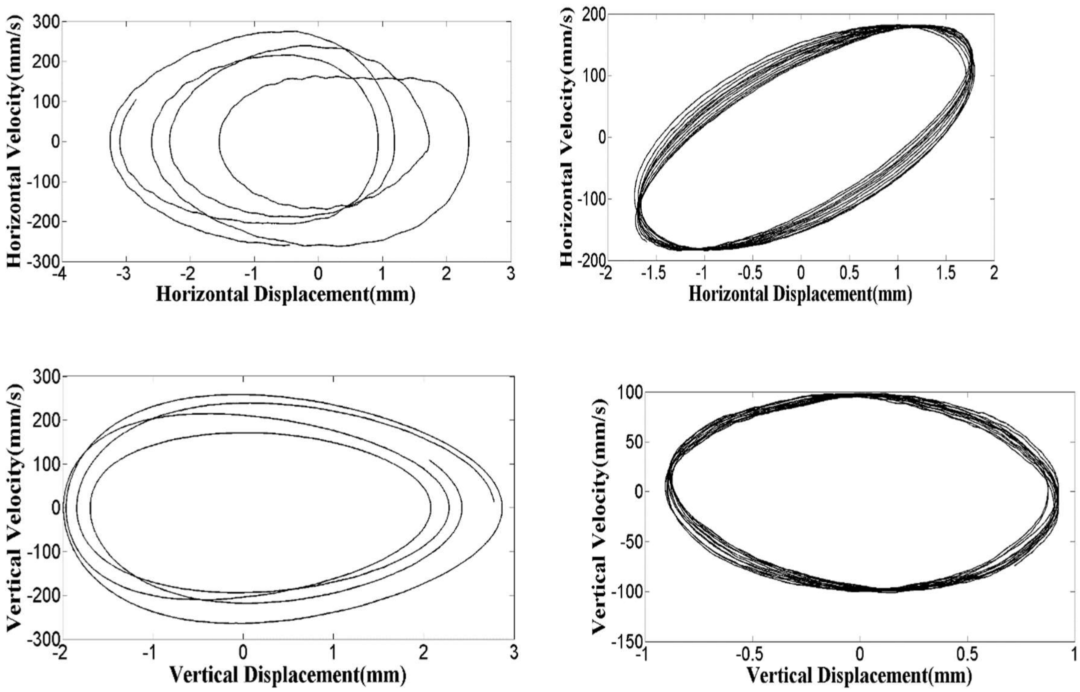

Figure:3 Comparison *of Poincare graph*

According to figure 3 We verified the computational model by comparing the computational data with the experimental data and by looking at the TDR, FFT, and Poincaré chart. The validated computational model will use to achieve acceleration (mm/s2), displacement (mm), and velocity (mm/s2) for different motor angle (α), motor speed for both horizontal and vertical directions. The values are shown in Table:3. As per Table :4 we are comparing the amplitude data for the different motor angle(α), with same motor speed(1000RPM) for better flow rate. Table:5 helps to compare the Dynamic motion behaviour with different Motor angle(α), with same motor speed(1000RPM).

Angle (degree)	Speed (rpm)	Acceleration (mm/s^2)		Displacement(mm)		Velocity(mm/s^2)	
		horizontal	vertical	horizontal	vertical	horizontal	vertical
28	1000	$-5.6X10^4$	$6X10^4$	-4.2	-4.3	-300.5	378
	1050	$3.9X10^4$	$4.5X10^4$	6.5	-6.4	300	-400
	1100	$-5X10^4$	$4X10^4$	-3.3	2.7	-200.9	200.5
30	1000	$2.8X10^4$	$1.5X10^4$	1.7	0.8	100.9	100
32	1000	$-5.6X10^4$	$3.9X10^4$	-6.8	6.6	-300.9	300

1050	$3X10^4$	$-3.9X10^4$	-6.8	6.6	-300.9	300
1100	$-5X10^4$	$1.5X10^4$	-4.3	-4.1	300.2	400

Table 3: computational data at different motor angle

Table 4: Comparison of amplitude and dynamic motion behaviors data

Data	Angle(degree)	Speed (rpm)	Amplitude (mm)	Dynamic motion
Computational	**28**	**1000**	**4.5**	Multi periodic
Computational	**30**	**1000**	**1.75**	Multi periodic
Computational	**32**	**1000**	**4.3**	Multi periodic

Based on study of above table no 4, we had found that motor angel 28^0 and 32^0 are optimized nearby value for better amplitude and effective dynamic motion behaviour. Amplitude value at motor angle 28° is higher than the motor angle 30° and 32^0. So, flowrate calculation is preferred for motor angle 28° compared to motor angle 30^0 and 32°.
For flow rate calculations following equation is used which is mentioned in the equation 1.

Flow rate of grain (Q) =ρ*A*v -------------- (1)

Here, it is assumed that grains are have uniform geometry which mean constant area and all grains are homogeneous in nature which led to conclude the constant density of grain. It means that velocity of grain flow is effective parameter to improve production rate of system. For calculating the flow rate computationally using different velocities for three different speeds as per table 3 use the equation mentioned as below as per equation 2. consider the flow rate experimentally as 4 tons per hour.

Q1/Q2 = V1/V2 -----------(2)

In above equation Q1 is flow rate of experimental, Q2 is flow rate of computational for different speed, v**1 is velocity** of grain at 30^0 angle and **v2** is velocity of grain at 28^0 angles with three different speeds.

Table 5 Computational Data of Reciprocating Vibro Separator at 28º

Angle (degree)	Speed(rpm)	Flow rate (tons per hour)	Dynamic motion
28	**1000**	**14.99**	Multi periodic
28	**1050**	**15.86**	Multi periodic

28	**1100**	**7.9649**	chaotic

As we know as the velocity increases the flow rate also increase but from the above table 5 it has been observed that chaotic dynamic motion behavior also plays vital role so at 28^0 angle and speed of 1100 the flow rate decreases. Hence at 28^0 angle and 1050 rpm the flow rate is maximum.

Conclusion:

In present work, a computational model has been developed for reciprocating vibro-separator. Dynamic motion analysis has carried out along with vibration responses of system. Overall computational data has validated with industrial data before proceed for further alteration. After validating computational model, significant parameters have altered to evaluate maximum flow rate with better dynamic motion of system. Hence major outcome of present work has concluded as follows:

(1) As per computational model analysis we had found higher amplitude when motor angle is 28^0 and 32^0. If we compare computational analysis and investigational data then we will get higher amplitude and better dynamic motion in case of motor angle 28^0 and motor speed 1000 rpm and 1050 rpm.

(2) The reciprocating vibro separator's flow rate is higher at a motor angle of 28° and a motor speed of 1050 rpm. Additionally, it is determined that the reciprocating vibro separator's flow rate is higher at motor angles of 28° and motor speeds of 1000 rpm. The preferred motor speed is between 1000 and 1050 rpm as opposed to 1100 rpm, based on a higher flow rate at a motor angle of 28°. Additionally, analysis shows that the reciprocating vibro separator's flow rate is higher at motor angles of 28° than 30°.We will suggest the industry to set the motor angle 28^0 and motor speed 1000 or 1050 rpm to obtain the higher flow rate.

Present work will be useful for vibro-separator manufacturer to develop efficient and cost-effective product development. This work will be also useful for end user to operate present installed system with optimize parameters.

References:

1. Jianzhang Xiao, Xin Tong "Characteristics and efficiency of a new vibrating screen with a swing trace" Particuology xxx (2013)
2. Liu Chusheng , Wang Hong , Zhao Yuemin , Zhao Lala, Dong Hailin "DEM simulation of particle flow on a single deck banana screen" International Journal of Mining Science and Technology 23 (2013) 273–277
3. HE Xiao-mei, LIU Chu-sheng, "Dynamics and screening characteristics of a vibrating screen with variable elliptical trace"China University of Mining & Technology, Jiangsu 221116
4. Monica Soldinger, "Transport velocity of a crushed rock material bed on a screen" Minerals Engineering 15 (2002) 7-17
5. Baragetti, Sergio. "Innovative structural solution for heavy loaded vibrating screens." Minerals Engineering 84 (2015): 15-26.

6. Golovanevskiy, Vladimir A., et al. "Vibration-induced phenomena in bulk granular materials." International Journal of Mineral Processing 100.3 (2011): 79-85
7. Xiao, Jian zhang, and Xin Tong. "Characteristics and efficiency of a new vibrating screen with a swing trace." Particuology 11.5 (2013):601-606
8. Sudhakar, I., S. Adi Narayana, and M. Anil Prakash. "Condition Monitoring of a 3-Ø Induction Motor by Vibration Spectrum analysis using Fft Analyser-A Case Study." Materials Today: Proceedings 4.2 (2017):1099- 1105
9. Ramatsetse, Boitumelo, Khumbulani Mpofu, and Olasumbo Makinde."Failure and sensitivity analysis of a reconfigurable vibrating screen using finite element analysis." Case Studies in Engineering Failure Analysis (2017): 40-51.
10. Jiang, Haishen, et al. "Dynamic characteristics of an equal-thickness screen with a variable amplitude and screening analysis." Powder Technology 311 (2017): 239-246.
11. Jiang, Haishen, et al. "Process analysis and operational parameter optimization of a variable amplitude screen for coal classification." Fuel 194 (2017): 329-338.
12. Jiang, Haishen, et al. "Kinematics of variable-amplitude screen and analysis of particle behavior during the process of coal screening." Powder Technology 306 (2017): 88-95.
13. Dong, Hailin, et al. "Influence of vibration mode on the screening process." International Journal of Mining Science and Technology 23.1 (2013): 95-98.