# Non-Linear Motion Analysis of Reciprocating Vibro separator

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***Abstract—*** *In this paper, dynamic motion behavior of reciprocating vibro separator model has developed and analyzed. Effective of 3 different elasticity of vibro-pad material has computed and nonlinear dynamic motions have investigated. Based on previous empirical data computational model has validated with elasticity value of 25MPa, vibro motor at 1000 rpm and vibro motor angle (α) 30º has resulted in minimum horizontal displacement and periodic motion of system. For the motion analysis Poincaré, Fast Fourier Transit (FFT) & Time data graphs have used. The computational model of reciprocating vibro separator has observed significant resembling with industrial case study.*

***Keywords—* *Dynamic Motion analysis, Model validation, Material property.***

## I. INTRODUCTION

We are living in world where technology is most important part of life. Every day new techniques are implemented in different fields but still some of area is having lack behind in usage of modern technology. Agriculture is one of them where some processes have to improve. Like separation process in which researchers are working so that their work will give a very useful output. In separation process Reciprocating vibro separator is used. Some work has been performed for improving its efficiency and its strength.

The present work is to investigate the dynamic motion behavior of Reciprocating vibro separator by using ANSYS software besides using DEM simulation method. In the past, The set up for experimental work is done on the placement of motor at the up side center place of vibro separator box whereas in present work the motor is connected at two side center place of separator box. Aim of this paper work is to analyse the Amplitude and dynamic motion behavior of Reciprocating vibro separator as it has significant effect on particle flow rate and velocity. Authors have attempted to validate the computational model with industrial case study

## II. LITERATURE SURVEY

Here Lala Zhao, Yuemin Zhao, Chunyong Bao ,Qinfu Hou , Aibing Yu (2016) have noticed that the average velocities of simulations with both spherical and non- spherical particle models in each case show similar trends with the tests. For most cases, the velocities of spherical particles are more highly over-predicted than those of non-spherical particles because of the simplification of particle shapes.

Changlong Du, Kuidong Gao, Jianping Li, and Hao Jiang (2012) have used the Separator which has unbalanced mass rotor at center & after that they said that by analysing the screening process of three different vibration screens, it proves that the variable linear vibration screen has better power distribution and screen surface movement the flexible screen surface can increase the amplitude of the screen surface and reduce the material blocking phenomenon. The screen experiment results of the two style screen surface vibration screens show the huge advantage of flexible screen surface than fixed screen surface in screen efficiency and avoiding material crush and it also provides a powerful proof to verify the correctness of the simulation work. Xiaohao Li, Mingxu Ma (2012) The research results which carried out in the paper showed that, about the nonlinear vibration system which supported by the soft nonlinear characteristics spring, the amplitude value of the nonlinear system can be automatically compensated when the vibrating mass of the vibrating system fluctuating in small-scope, which make the amplitude approximate remaining constant. ZHAO Lala, LIU Chusheng, YAN Junxia (2010) indicate that The amplitude and the vibration direction angle have a great effect on the particle average velocity and the average throw height considered over the normal range of linear screen parameters. The vibration frequency and the inclination angle of the screen plate have a small influence. To obtain the ideal sieving effect for materials that are difficult to sieve the frequency and amplitude of vibration, the inclination angle of the screen plate and the vibration direction angle should be chosen as 13 Hz, 6.6 mm, 6° and 40°, respectively. A.V. Ramana Rao, CH. Bhanu Prakash, G.H. Tammi Raju(2012) They studied on the separator which was working on linear motion where they give the suitable parameter for motor rpm range from 1000 rpm to 1200 rpm & also use the motor angle from 25 degree 45 degree. Monica Soldinge (2002) has use the monte carlo simulation to check the effect of angle between base line & separator box bottom layer line ,then he conclude that for the β value of 5 degree the rpm speed is range from 1000 to 800. Liu Chusheng , Wang Hong a, Zhao Yuemin , Zhao Lala , Dong Hailin (2011) have tried to get the optimum angle between base line & separator box bottom layer line β & conclude that the increment of screen deck has a same effect on banana screening process as inclination of discharge end And when the values of inclination of discharge and increment of screen deck inclination are 10 degree to 5 degree the banana screening process get a good screening performance in the simulation.

Dong Hailin, Liu Chusheng , Zhao Yuemin, Zhao LalaThe (2011) they studied on linear, circular & elliptical motion of screen they said that travel velocity of the particles during linear screening is the fastest. This results in a thin material layer but the lowest Overall screening efficiency. The circular mode gives the lowest particle velocity along the screen but the highest screening efficiency. In this case, the material layer is thick but the interaction between particles and the penetration effect are enhanced. Jianzhang Xiao, Xin Tong (2011) has investigated in this paper that the effects of vibration parameters including frequency and swing declination angle on screening efficiency through DEM 3D simulations leading to a set of empirical formula by regression analysis to describe the relationship between efficiency and vibration parameters for swing vibration screen.

Vladimir A.Golovanevskiy, Vasily A. Arsentyev, Iliya I. Blekhman, Vladislav B. Vasilkov, Yuliy I. Azbel, Kira S. Yakimova (2011) says that the description of specific vibration-induced phenomena presented in this paper provides the basis for development of materials handling technologies and process equipment to affect bulk material flow behaviour with vibration. To ensure the highest vibration-aided bulk granular material separation efficiency, it is suggested that the amplitude and frequency of vibration should be selected on the basis of providing the vibration overloading factor w values of w≈3 or slightly higher. Further research needs to focus on the development of an overall model describing behaviour of granular material under vibration.

Paul W. Cleary, Matthew D. Sinnott, Rob D. Morrison (2009) says that the two key components of screen separation and their differing dependency on the screen acceleration area:

1. Fine particles percolate through the dense shearing bed: Higher accelerations lead to more dilation of the bed and to higher shear which improve this component of screen flow. This is responsible for more rapid stratification of the bed and provision of a layer of fine material adjacent to the screen cloth.
2. Particles smaller than the screen aperture size and which are adjacent to the cloth are captured by and pass through holes in the screen cloth. This process is dependent on the size and shape of the particle and on the flow. The faster the flow speed and the denser the bed directly above the cloth, the lower is the chance of a particle being able to pass through an opening.

Lijun Wang, Zhenjun Ding, Shuang Meng, Huijun Zhao, Huiqiang Song For a particle on the screen moving from the front to the back of the screen, the regimes of the different particle behaviors such as stable periodic motion, period-doubling bifurcation motion, bifurcation motion, and the chaotic motion, were obtained. Chaotic motion was found to beneficial in separating particles effectively from other agricultural threshed materials and avoids at the same time particles accumulating on the screen and enhances the probability that the particle penetrates the screen hole. A detailed investigation on this aspect (passage rate) was not performed and remained open problems.

J. LI, C. WEBB, S. S. PANDIELLA and G. M. CAMPBELL (2002) concluded that For a screening system involving granular materials, it has demonstrated that the critical feeding rate or bed depth for the most effective screening operation can be determined via conducting the DEM simulation. Further work will focus on the implementation of advanced experimental techniques to measure the process and to validate the model.

Zhao Lala, Zhao Yuemin, Liu Chusheng, Li Jun , Dong Hailin (2011) describe that Vibration parameters have significant effects on the circularly vibrating screening process. Too small a vibration amplitude, a throwing index, or a screen-deck inclination angle will cause the accumulation of particles on the deck. But too large values of these parameters will also reduce screening efficiency. HE Xiao-mei, LIU Chu-sheng(2008) have Studied on vibro separator & told that the motion of vibro separator is following the elliptical trace. A theoretical kinematic analysis of the vibrating screen was done to study how varying different parameters affects the motion of the screen. Kinematics parameters of the vibrating screen that motion traces are linear, circular or elliptical are obtained. Their work also conclude that the position of the exciter axle center relative to the center of gravity of the vibrating screen is extremely important for screening efficient Thus; we can design a vibrating screen with higher processing capacity without increasing power consumption by adjusting the relative position of the axle center. Zhao Yue-min, Liu Chu-sheng, He Xiao-mei, Zhang Cheng-yong, Wang Yi-bin, Ren Zi-ting (2009) says that the dynamic response analysis shows that adding stiffening angle and longitudinal stiffeners to both side plates is able to decrease transverse deformation of side plate and ameliorate the twist deformation of screen frame. The maximum transverse displacement of the vibrating screen is 0.13 mm.

## III. COMPUTATIONAL ANALYSIS AND RESPONSES

The reciprocating vibro separator has three type of vibration mode. Out of which elliptical vibration mode is having good result of screening compare to others. To observe that elliptical motion the computational model of reciprocating vibro separator is modeled out in CRE-O 3.0 and analyze in ANSYS 14.5. Model analysis has performed and corresponding 6 mode frequencies were tabulated in table 1.

**TABLE 1**
**MODEL ANALYSIS FREQUENCIES**

| Mode | Frequency(Hz) |
|---|---|
| 1 | 174.47 |
| 2 | 174.47 |
| 3 | 185.35 |
| 4 | 384.18 |
| 5 | 385.12 |
| 6 | 442.07 |

Out of 6 mode of failure, it has imperially concluded the mode 3 is critical mode of failure. Corresponding critical frequencies have observed 185.35 Hz frequency and based on half power bandwidth concept the damping ratio of vibro-pad has investigated and calculated value for ζ is 0.0017. Frequency response graph for mode 3 at 185.35 Hz has analyzed at 70% marginal amplitude of peak which response the concern frequencies as shown in enlarged view. From calculated value for ζ, authors can calculate the damping coefficient for mass & stiffness as ANSYS input parameters.

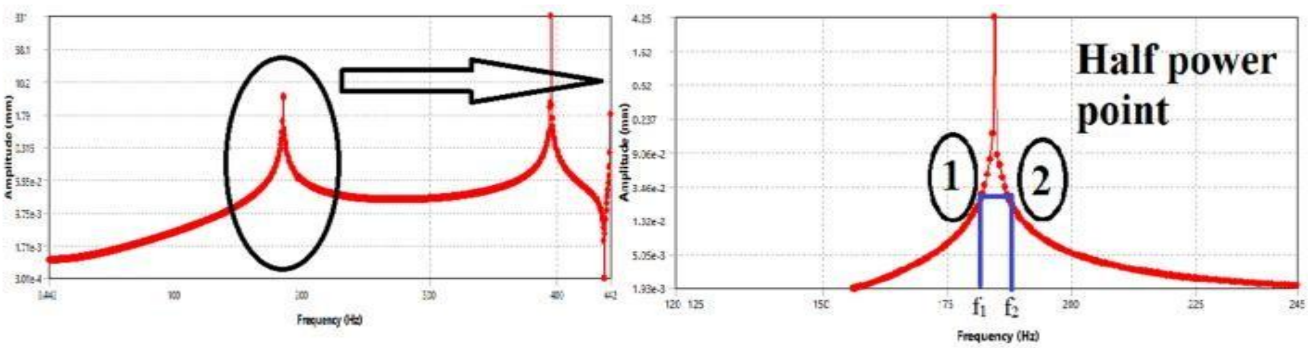



**FIGURE 1: Frequency response graph**

Computational analysis of developed model is performed with different input parameters like motor angle (α), motor speed & properties of Vibro-pad as varying parameters and the dynamic motion behavior of vibro separator is observed.

From the earlier data the range of motor angle is selected from 25 to 35 degree. Also range of motor rpm is selected from 1000 to 1200 rpm. Then the computational work for different motor angle and different speed combination is performed and corresponding FFT plots and Poincaré graphs have plotted for motion analysis.

## IV. INDUSTRIAL ON SIGHT EXPERIMENT

The setup was prepared as per the computational work. Here the two vibro motors are running at 1000 rpm. The variation in motor speed is ± 20 rpm. Each vibro motor is having 0.5 Hp power. The Experimental Setup is running in between 980 to 1020 rpm motor speed with 30 degree motor angle. The experimental work is performed at **GAJANAND** industries at **UNJHA.**

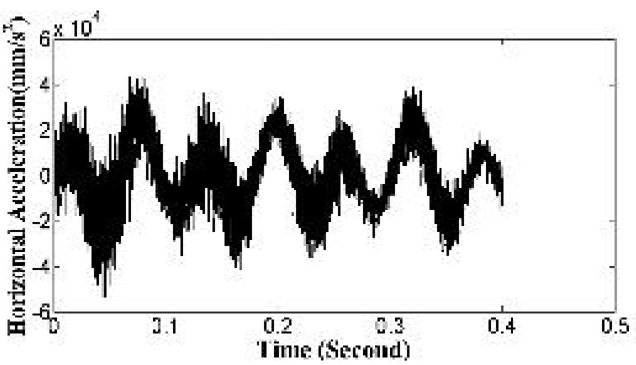

**FIGURE 2: Experimental Setup in GAJANAND Industries**

Here the separator box has two motor connected at two side walls at the middle point of separator box height. Four unbalanced masses are connected to each motor, which has weight of 3.34 kg each. The experimental results are taken at 3 point, one point is at the top center place of vibro separator box and remaining two points are at top side end position of separator box as shown in figure 2. The piezoelectric accelerometers sensor (uni-axial) is used for picking up the vibration signals from the point on separator box. These special piezoelectric pickup type sensors are used with a frequency of range from 1-10 kHz. The sensitivity of sensor 107 mV/(m/s2) with integral electronics piezoelectric accelerometer (IEPE) input mode of sensor. The analyzer used to measure the acceleration data is made by Crystal Corporation. The model of analyzer is CoCo-80. As shown in figure 3.

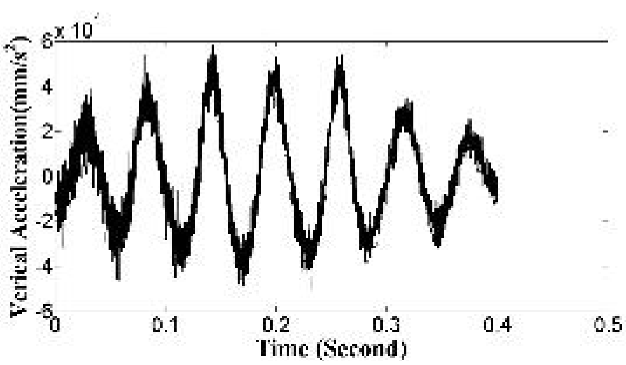

**FIGURE 3: Vibro Analyzer.**

## V. RESULT AND DISCUSSION

In the present work the material property of vibro-pad & Motor angle (α) is considered as the input parameter. From all that consideration of input parameter the motion of reciprocating vibro separator is observed. To observe the motion of vibro separator different tools are available. Out of which the time domain data, fast Fourier transform (FFT) & Poincaré are taken in consideration for motion behavior. The Reciprocating vibro separator box. The computational data & Experimental data both are taken for 10 KHz sampling frequency. As per one of the input parameter the vibro-pad elasticity is changed. For computational work the elasticity for vibro-pad is taken as 10 MPa, 25 MPa and 40 MPa. The computational model is Analyze based on motor angle (α) of 30 degree & 1000 RPM speed for all three elasticity. In experiment the speed of motor is varying between 920 rpm to 1020 rpm. The computational work is analyze for 0.4 to 0.5 set




**4(a)**




**4(b)**

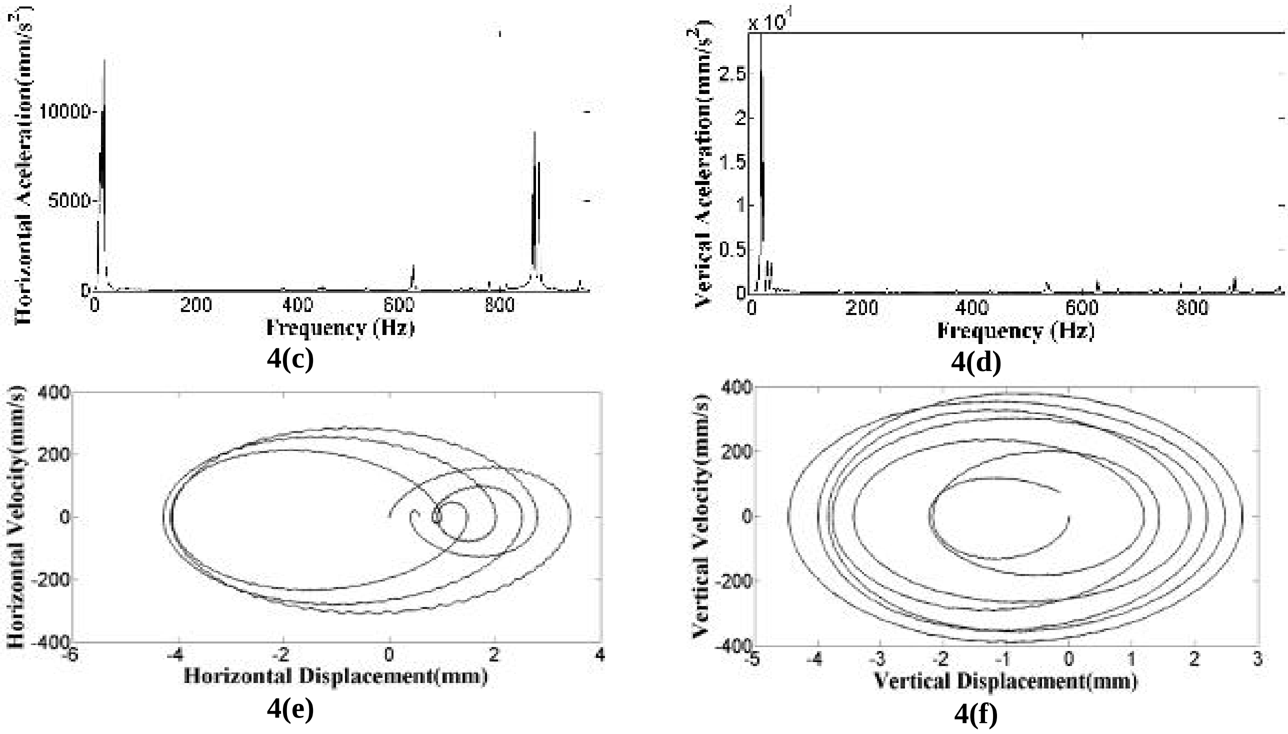



**FIGURE 4: Computational Dynamic Motion Analysis at 30 degree & 1000 rpm 40 Mpa elasticity**

Figure 4(a-b) are the acceleration graph that indicate that the acceleration value of vibro separator is higher in vertical direction compare to horizontal direction. Figure FFT plot have indicated the super harmonic response in horizontal direction and neither sub harmonic nor super harmonic responses have observed in vertical direction as shown in figure 4(c-d), which would lead to conclude the periodic behaviour of system. Figure 4(e-f) are Poincaré graph it shows that motion of reciprocating vibro separator has periodic motion in vertical and multi periodicity observed in horizontal direction. Horizontal Poincaré responses have displacement of +3 to -4 mm.

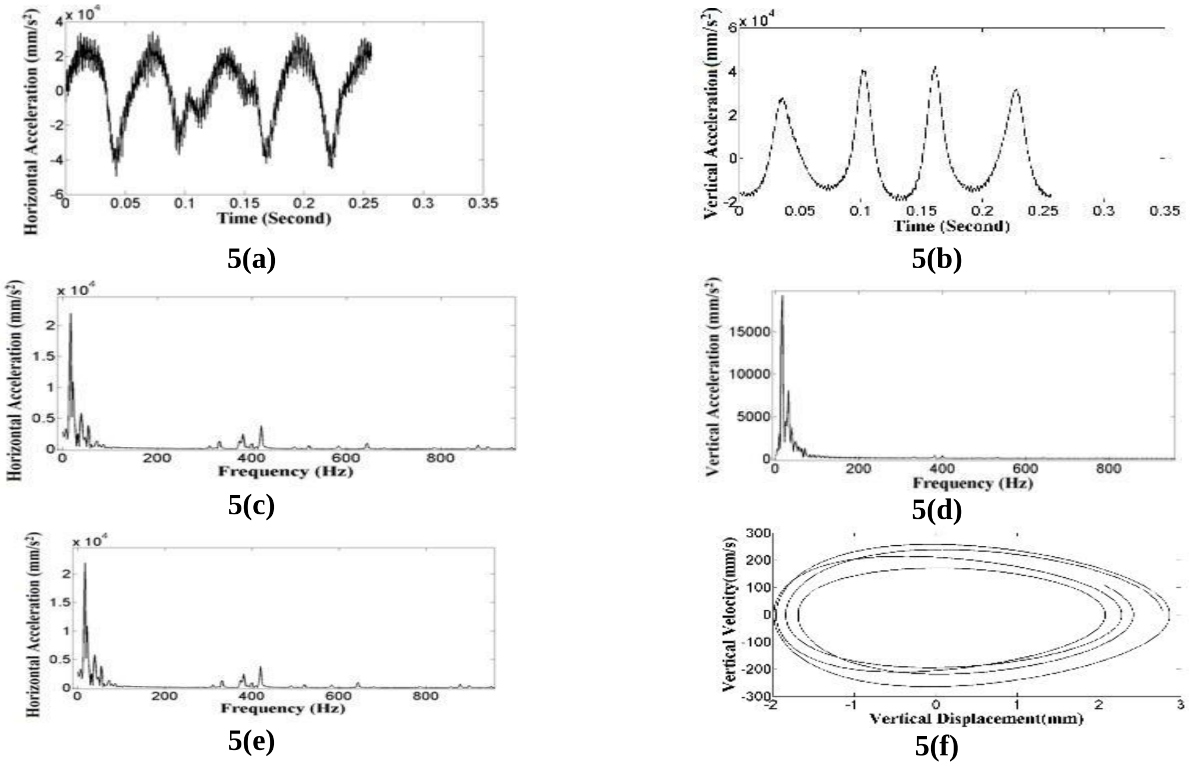
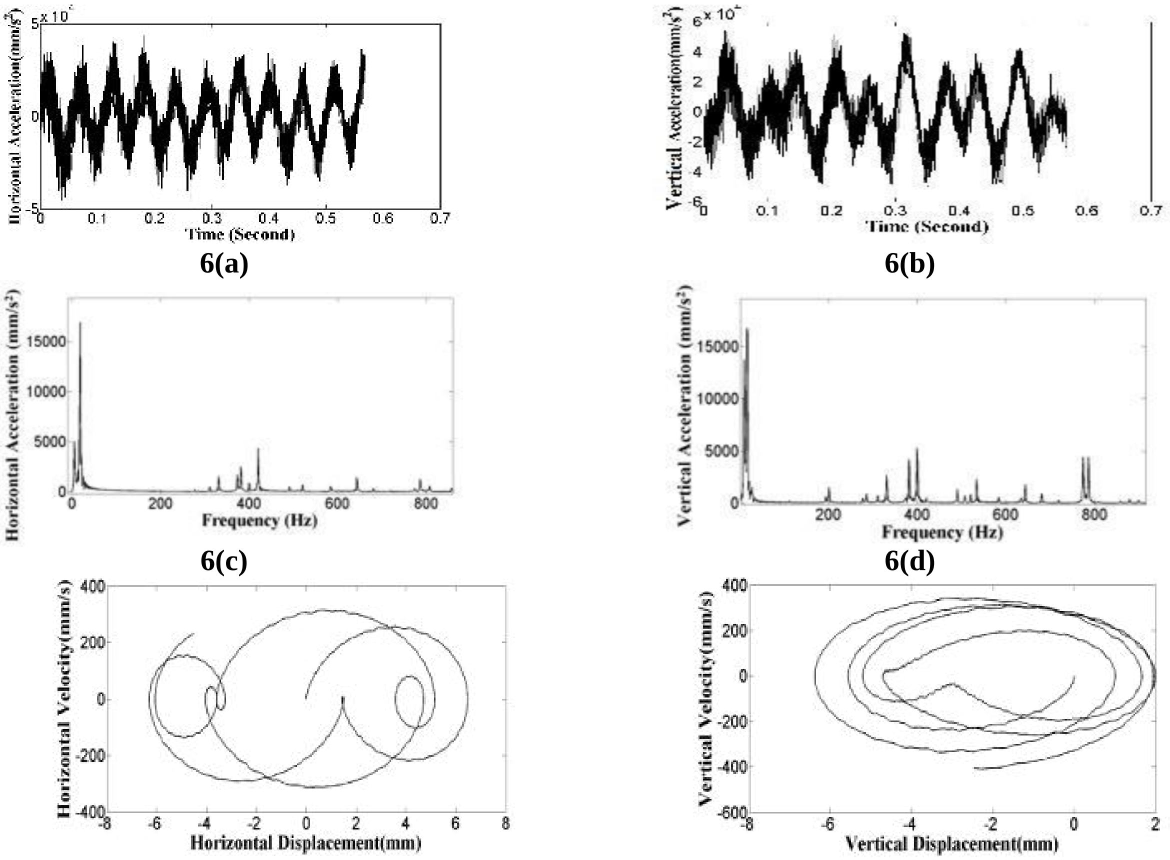



**FIGURE 5: Computational Dynamic motion analysis at 30 degree & 1000 rpm with 25MPa elasticity**

Figure 5(a-b) are shows that the value of acceleration in horizontal direction is approximately doubled than in vertical direction. As we decreases the elasticity the clear stable equilibrium time response have observed in horizontal as compare to horizontal time response for elasticity of 40 MPa. Vertical time responses have clear indication of the periodic motion behavior of system. FFT plots have mentioned that the motion is periodic as no such super harmonic or sub harmonic peaks have observed as shown in Figure 5(c-d). Figure 5(e-f) are Poincaré maps for horizontal and vertical direction clearly indicated periodic motion with less multi periodicity as compare to rubber elasticity of 40MPa. Horizontal Poincaré responses have displacement of +2.2 to -3.5 mm.



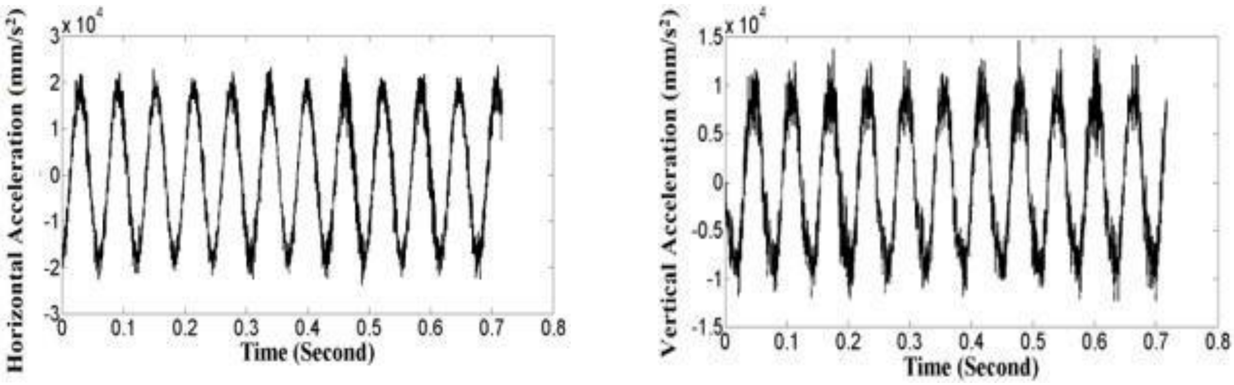

6(a) 6(b)

6(c) 6(d)

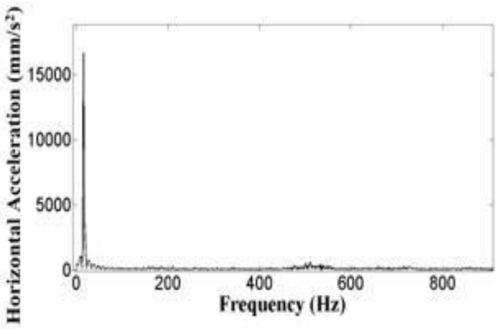
6(e) 6(f)

**FIGURE 6: Computational Dynamic motion analysis at 30 degree & 1000 rpm with 10 MPa elasticity**

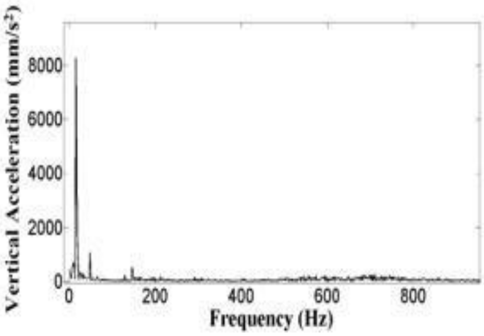
On further decreases the elasticity of vibro-pad, more instable responses in both directions have observed as shown in Figure 6(a-b). Figure 6(c-d) are the FFT plots have sub harmonic responses in horizontal direction with significant sidebands in horizontal responses while in vertical responses have observed with higher range super harmonic responses. Poincaré maps clearly indicated 5T periodicity in horizontal responses and multiple periodicities in vertical responses. Horizontal Poincaré responses have displacement of +7 to -6.3 mm.



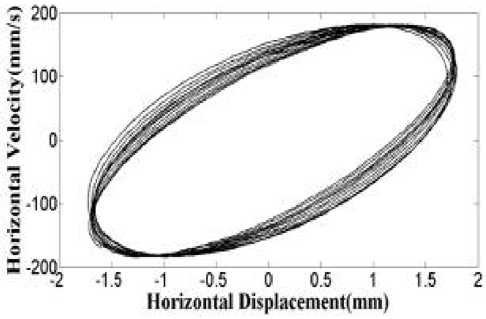

7(a) 7(b)



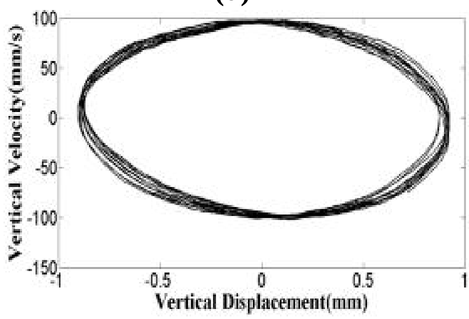

7(c)




7(d)




7(e)




7(f)

**FIGURE 7: Experiment Dynamic motion analysis at 30 degree & speed is varying between 980 rpm to 1020 rpm.**

Experimental time responses have concluded stable and periodic response to system as shown in Figure 7(a-b). Figure 7(c-d) are the FFT plot that indicate that the motion is periodic. Figure 7(e-f) are Poincaré maps which clearly indicate periodic motion behavior of system. Horizontal Poincaré responses have displacement of +1.8 to -1.75 MM.

Computational model with elasticity value of 25MPa, vibro motor at 1000 rpm and vibro motor angle (α) 30° has resulted in horizontal displacement of 5.7 mm with periodic responses. As elasticity increases horizontal displacement of system has increased to 7 mm and multi periodicity have reported. And as elasticity of vibro-pad decreases horizontal displacement of system has increased to 13.3 mm and multi periodicity have reported. Horizontal amplitude responses have reported more than the vertical amplitude responses in Time domain responses in computational and experimental as well. Computational model has validated with industrial experiments.

## VI. CONCLUSION

In the present work, computational model has developed and analyzed for different nonlinear motion behavior of vibro separator with 3 different elasticity of vibro-pad. Require damping coefficient of mass and stiffness has evaluated using half power band width method. Analyzed computational model have shown significant validation with industrial case study which lead to conclude the following conclusions:

1. Authors have lead to conclude that as decreasing the elasticity of vibro pad material it will make the system more and more unstable as shown in figure4(a-b), 5(a-b) & 6(a-b).
2. Nonlinear motion behaviors of system have concluded that system has less multi periodicity with at 25MPa elasticity of vibro pad in computational model which shown more resembling with experimental Poincaré responses.
3. Effective operating parameters to be concluded from Computational model with elasticity value of 25MPa, vibro motor at 1000 rpm and vibro motor angle (α) 30° has resulted in minimum horizontal displacement of 5.7 mm bi-directional with periodic responses. Authors would like further extend this work for varying motor angle for future work.

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