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Modal and Harmonic Analysis in A Stepped Vibratory Bowl Feeder

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***Abstract*--Vibratory bowl feeders are commonly used in automated assembly systems to feed and orient variety of engineering parts. Vibratory bowl feeder mainly consists of a bowl connected to a base by three or four inclined leaf spring. Feeder causes a coupled rotation around its vertical axis due to constraining of the leaf spring. The feeder is activated by electromagnet.The investigation proposes the development of a model that predict the influence or the effect of the vibration amplitude in the orientation efficiency. The model was based on the identified parameters, such as part's geometry and orientation, to optimize the design and performance of vibratory bowl feeder.In this paper,the developed model can used to reduce the noise; nonlinear motion of the partsand to improve the feeding efficiency. The model has been verified by means of modal and harmonic analysis and validated through experimental setup.**

1.INTRODUCTION

Vibratory feeders commonly known as a bowl feeder are self-contained devices consisting of a specially shaped bowl designed to orient the parts to a specific direction in industrial practice.In modern automation system, vibratory bowl feeder is used in dedicated assembly system and it is designed to deliver parts at rates approximately one part per second(refer fig.1). Bowl feeders are intrinsically not flexible. Moreover they are faced with some essential design problems seriously affecting their functionality.

In previous work on vibratory bowl feeder theoretical analysis of vibratory parts feeder to find out feeding mechanism was done by A.H.Redford and G. Boothroyd[1]. To improve feeding efficiency Boothroyd[2] developed automatic orienting of parts in the form of various orienting devices. McDonald and Stone[3] introduced a linear vibratory feeder using the Mac Pascal language. S.Okabe[4] described a method of calculating natural frequency of vibratory bowl feeder (1981).Diana Ioana Popescu[5] (1986) described the motion of the bowl by preparing a model for dynamic calculus.Dennis .H.Shreve [6] (1994)in Introductionto Vibration Technology, detect when machine is developing problem and also identify a specific nature of problem. Han and Y.Lee (2000) [7] chaotic (confusion) dynamic of repeated impact design.Nebojsa I. Jaksic ,(2001)[8] research describes the development of a model of part behaviour required for reorienting a part with an air-jet-based computer controlled orienting system. In the same year, N.F. Edmondson (2001)[9], identified automated component handling requirements in a small batch multiple variant production system .S.B. Choi and D.H. Lee (2003) [10] done the modal analysis and control of a bowl parts feeder activated by piezoceramic actuators.Patrick S. K. Chua and F. L. Tan (2006)[11] and J.a Vilan Vilan (2009)[12] alsodone the work on dynamic computer simulation of parts feeding on a vibratory bowl feeder and behaviour of the part. Emiliano Mucchi (2012)[13]had done the elastodynamic analysis of vibratory bowl feeder. Suresh(2013)[14] determines the natural resting orientation of parts. Despite of this work, we use to the controller and electromagnet to run the vibratory bowl feeder.

Two or three electromagnetsgenerate the force which drives the bowl; they are attached to the system either vertically or horizontally between base & the bowl. Generally electromagnet has two parts one is fixed to the base, carriesa coil supplied by an electric circuit, &the otherfixed to the bowl support moves with the bowl. The current in coil which produces a magnetic flux which accordingly causes movement of spare parts along an inner spiral track of the bowl.In vibratory bowl feeder, direction,amplitude &frequency of bowl, oscillation depends upon the design parameter of the feeder. Severely vibratory feeders are simple inline for specificapplication& new design are based on modifications of previous designs with whole process mainly driven by trial & error criteria.

Research work done till date has not been able to fullyaddress the problems of noise generation and vibration transmitted to the surrounding. As such improvement in dynamicperformance of vibratory system is important. In this sight, theauthor has developed a model of the feeder which predicts its dynamic behaviour.In presentwork; the first step is to create a Vibratory Bowl Feeder,with the help of Modelling Software in Finite Element Method. For this purpose we use commercial software (PRO-E) and modal characteristics of the proposed bowl parts feeder are analysed & compared it with experiment.

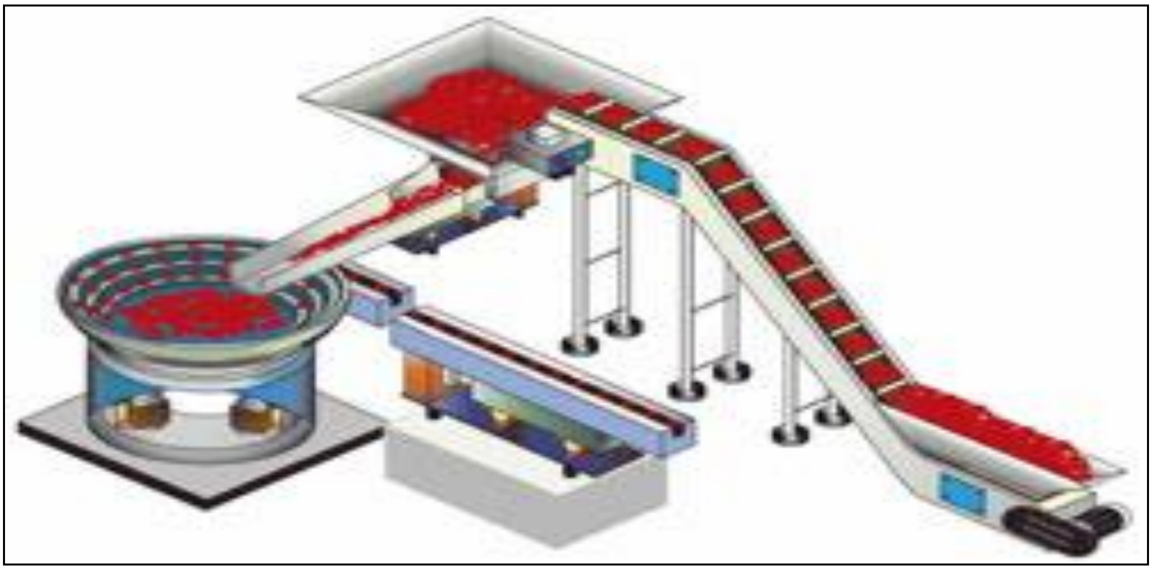

Fig.1 Dynamic vibratory bowl feeder system

2. MODELLING OF VIBRATORY BOWL FEEDER

Modelling of feeder is done in commercial software like Pro/ENGINEER Wildfire 5.All the dimensional and structural specifications are given in the table 1. In this software model is complicated to create in the Ansys software so that it is done in Pro-E software as shown in figure 2. To create the model various commands are used for like extrude, helical sweep, blend, cut etc.Inclined angle of inner track is 2º, inclined angle of the leaf spring is 17º.

Base diameter of the bowl is 309 mm and upper diameter of the bowl is 410 mm. Bowl has a centrally hole with 16 mm for fitting the washer and stud into it. Electromagnet having product specification is EM 320-SM with continuous duty cycle. Two electromagnets are used in the model as a drive unit maintaining 0.8 to 1.0 mm air gap.

Sr. No.	Parts	Material	Mass (Kg)	Density (Kg/Mm^3)	Dimensions (mm)
1	Bowl	SS	8.4	$7.74*10^{-6}$	Diameter = 309,Thickness =2.5, Pitch =50,Height =190
2	Washer	Al 6061	$2.96*10^{-1}$	$2.71*10^{-6}$	Upper diameter =70, Lower Diameter = 110 , Depth =20
3	Stud	SS	$1.61*10^{-1}$	$7.74*10^{-6}$	Diameter =16, Pitch=3
4	Base Plate	Al 6061	3.6	$2.71*10^{-6}$	Diameter = 320 , Thickness =20
5	3 Leaf Spring	Epoxy	$3.508*10^{-2}$	$1.299*10^{-3}$	Height =150,Width =30, Thickness = 6

Table.1Specifications of vibratory bowl feeder

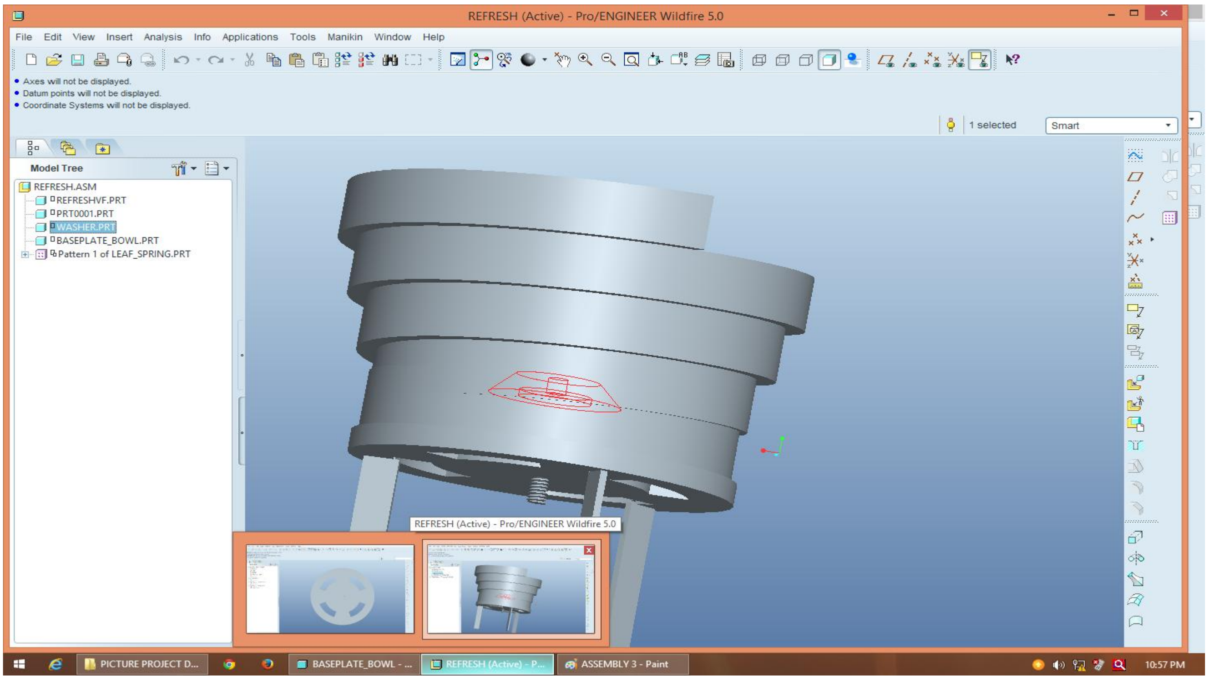

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Fig2.Modelling of vibratory bowl feeder in Pro-E

3. ANALYSIS OF VIBRATORY BOWL FEEDER

Though many pioneering researches have been undertaken to understand this principle, the motion of the bowl part feeder is not yet clearly demonstrated because of its structural complexity. By other means the construction of an appropriate FEM model can provide us various potentials for analysing modal characteristics and hence better understanding of the feeding principle. The finite element analysis for the proposed bowl part feeder has been performed by using commercial software packages.Finite element analysis is a technique to simulate loading condition on a design and determine design’s response to those conditions. ANSYS is complete FEA simulation software which is used in our work. FEA needed to reduce the amount of prototype testing and to simulate designs. In ANSYS we perform modal analysis and harmonic analysis from structural analysis.

3.1Modal analysis

In our work, Modal analysis is used to determine the natural frequencies and mode shapes of a structure. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. They are also used in a harmonic or transient analysis. Mode shape describes the configuration into which a component will naturally displace.ANSYS is used as the solver as well as pre-processor and postprocessor. Inpre-processor we import the geometry from Pro-E software. Figure 3.Shows the tetrahedron meshing of the bowl part feeder in pre-processor. Analysis type is modal and mode extraction method is block lanczos. In this FEM model has a total node points are 21189 and element are 41635. In this case, we used element type solid 45 which is having 24201 degrees of freedom and Shell 63 having 80694 degrees of freedom. Also Beam 4 having18 degree of freedom. For this three element types the total degrees of freedom is 104913.Post-processing is the final step in FEA process, in that 12 modes are to be extracted

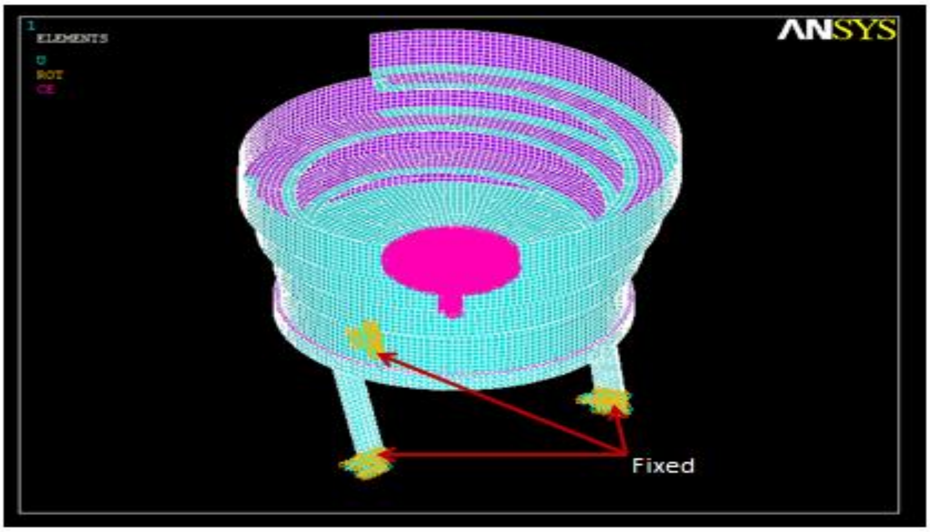
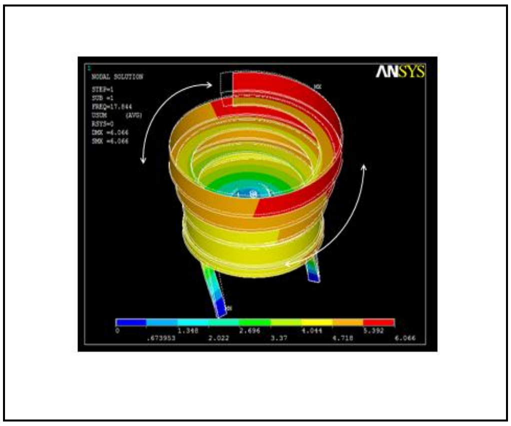


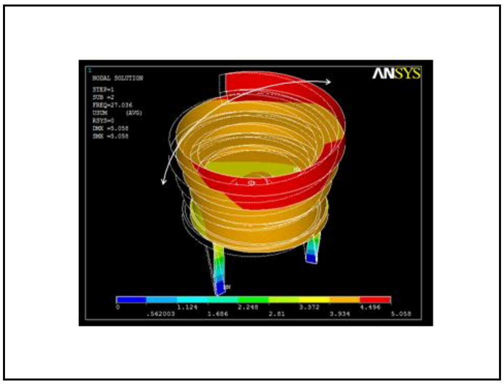
Fig:3. Formation of mesh in finite element analysis.

Mode shapes (figure 4.) of proposed bowl feeder taken from the general postprocessor in FEM analysis. The motions of mode shapes with modal frequencies are as follows-

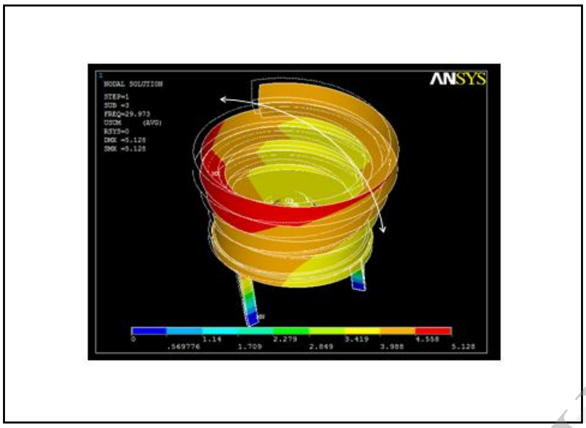
- First Mode: Reciprocating rotary motion with respect to vertical axis.
- Second Mode: Back and forth in Z-axis direction
- Third Mode: Back and forth in X-axis direction
- Fourth Mode: Up and down in Y-axis direction
- Fifth Mode: Back and forth in X-axis direction
- Sixth Mode: Reciprocating rotary motion with respect to vertical axis that is Y-axis
- Seventh Mode: Bending motion with respect to Z-axis direction
- Eighth Mode: Bending motion with respect to X-axis direction
- Ninth Mode: Bending motion with respect to X-axis direction
- Tenth Mode: Bending motion with respect to Z-axis direction
- Eleventh Mode: Bending motion with respect to X-axis direction
- Twelfth Mode: Up and down in Y-axis direction.



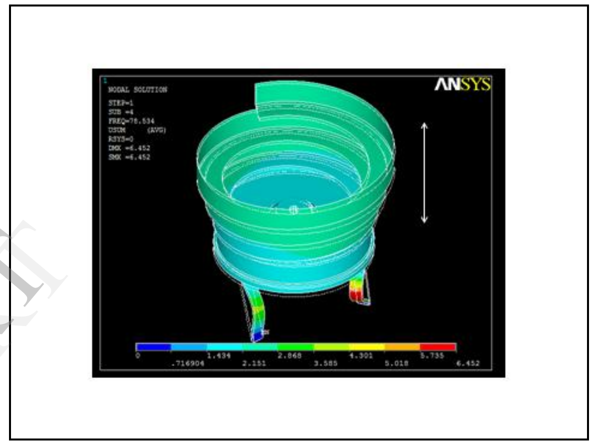
(a) 1st Mode Shape(17.844Hz)



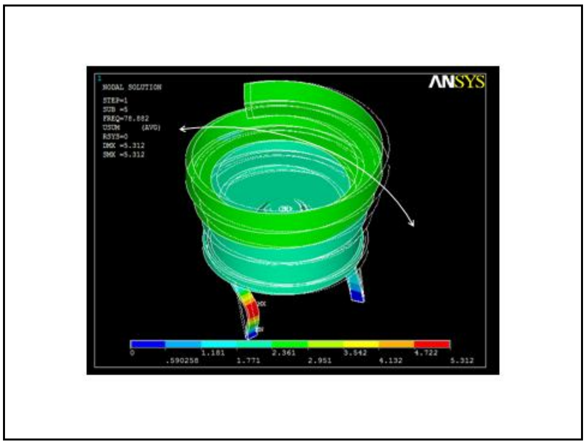
(b) 2nd Mode Shape (27.036Hz)



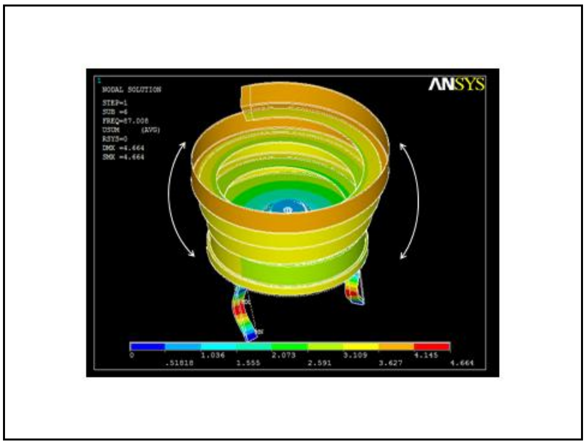
(c) 3rd Mode Shape(29.973Hz)



(d) 4th Mode Shape (78.534Hz)



(e) 5th Mode Shape (78.862Hz)



(f) 6th Mode Shape (87.008Hz)

(g) 7th Mode Shape (141.3Hz)

(h) 8th Mode Shape (142.635Hz)

(i) 9th Mode Shape (148.998Hz)

(j) 10th Mode Shape (170.454Hz)

(k) 11th Mode Shape (176.14Hz)

(l) 12th Mode Shape (184.536Hz)

Fig.4 Mode shapes at different frequencies

3.2 Harmonic response Analysis

Modal analysis outputs are used as input for the harmonic response analysis.In astructural system, any sustained cyclic load will produce a harmonic response. Harmonic Analysis result are used to determine the steady-state response of linear structure to loads that vary sinusoidally (harmonically) with time, thus enabling us to verify whether or not our designs will successfully overcome resonance, fatigue,and other harmful effects of forced vibrations.This analysis technique calculates the steady state, forced vibrations of a structure. The transient vibrations, which occur at the beginning of the excitation, are not accounted for in a harmonic response analysis. In this analysis, vibratory bowl feeder's response varies sinusoidal. A harmonic analysis is used calculate the response of the structure to cyclic loads over a frequency range and obtain a graph of amplitude verses frequency as well as phase angle verses frequency. The frequency spectrum is a plot of amplitude of a vibration response vs. frequency in time wave form. The frequency spectrum provides valuable information about the condition of a component. An important characteristic of a spectrum is that rotating component generates identifiable frequency as illustrated in following figures, (refer fig.6 - 9)

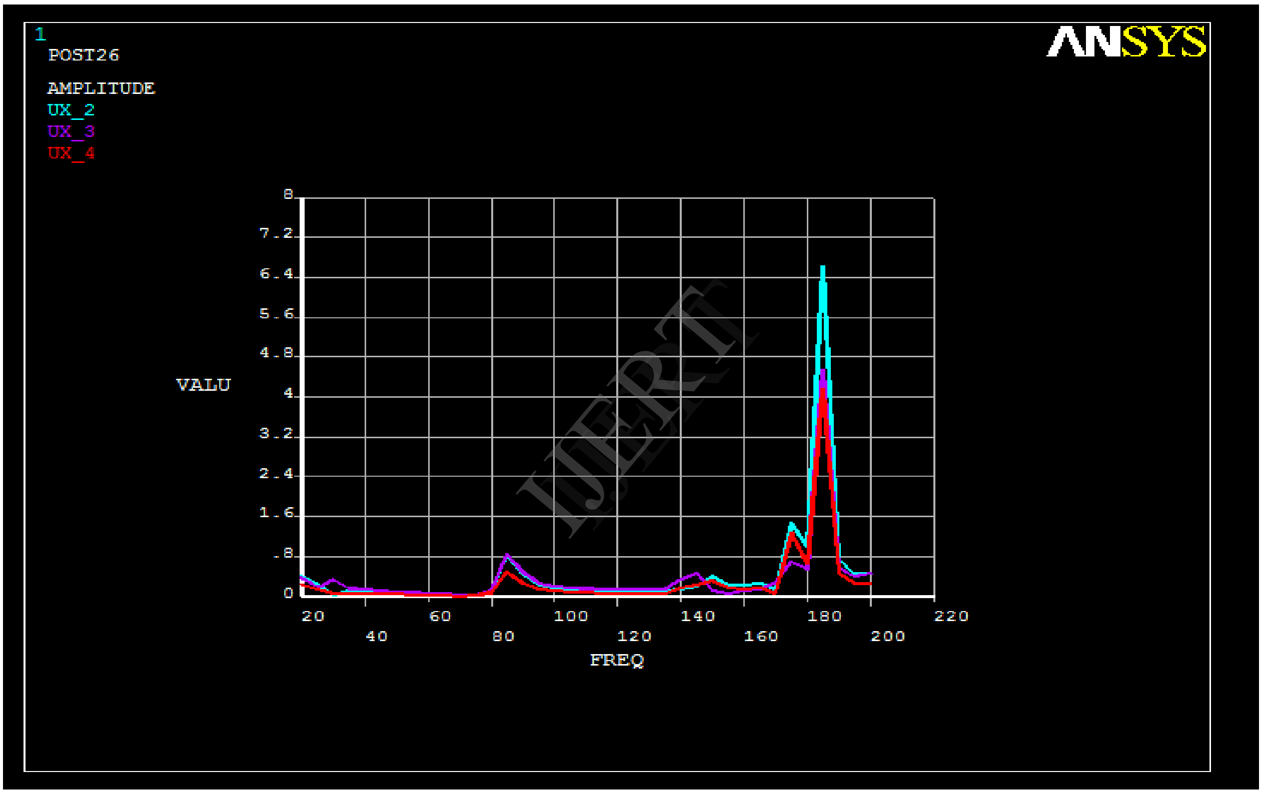


Fig 5. Amplitude in X-direction with different nodes Vs. Frequency

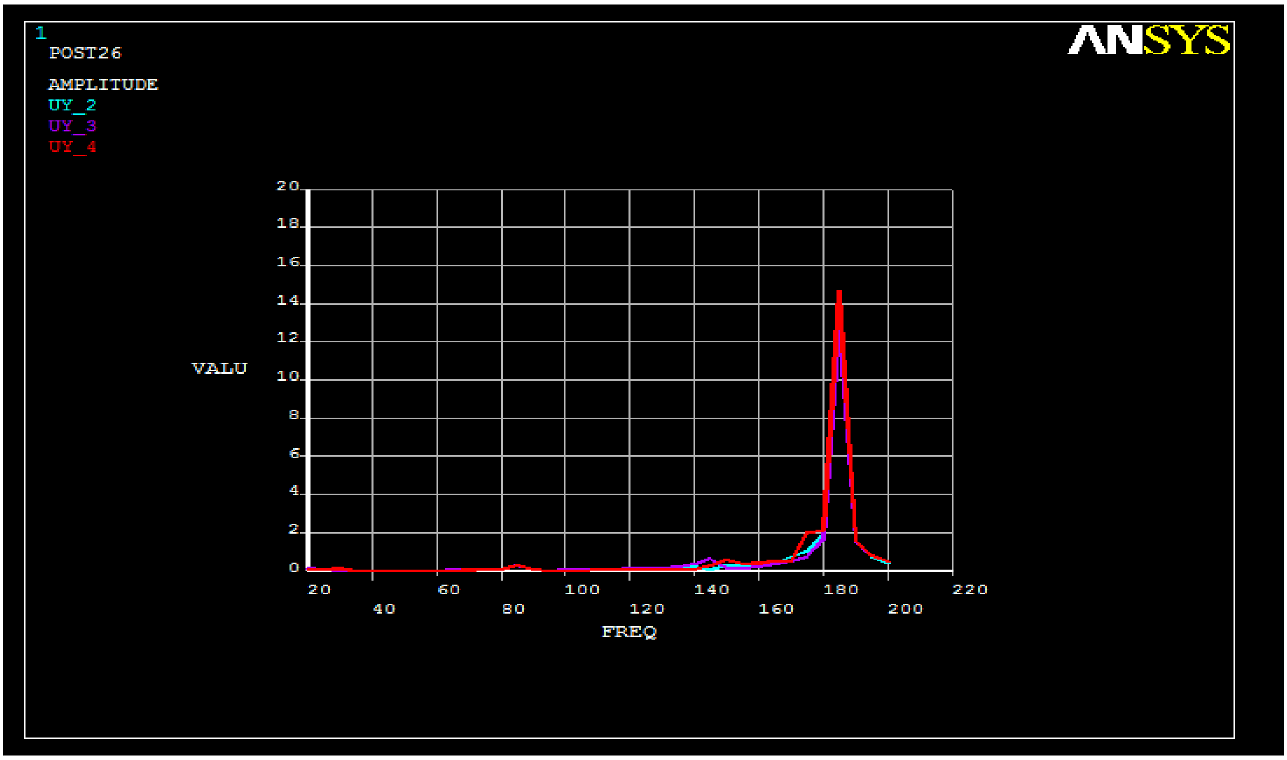


Fig 6. Amplitude in Y-direction with different nodes Vs. Frequency

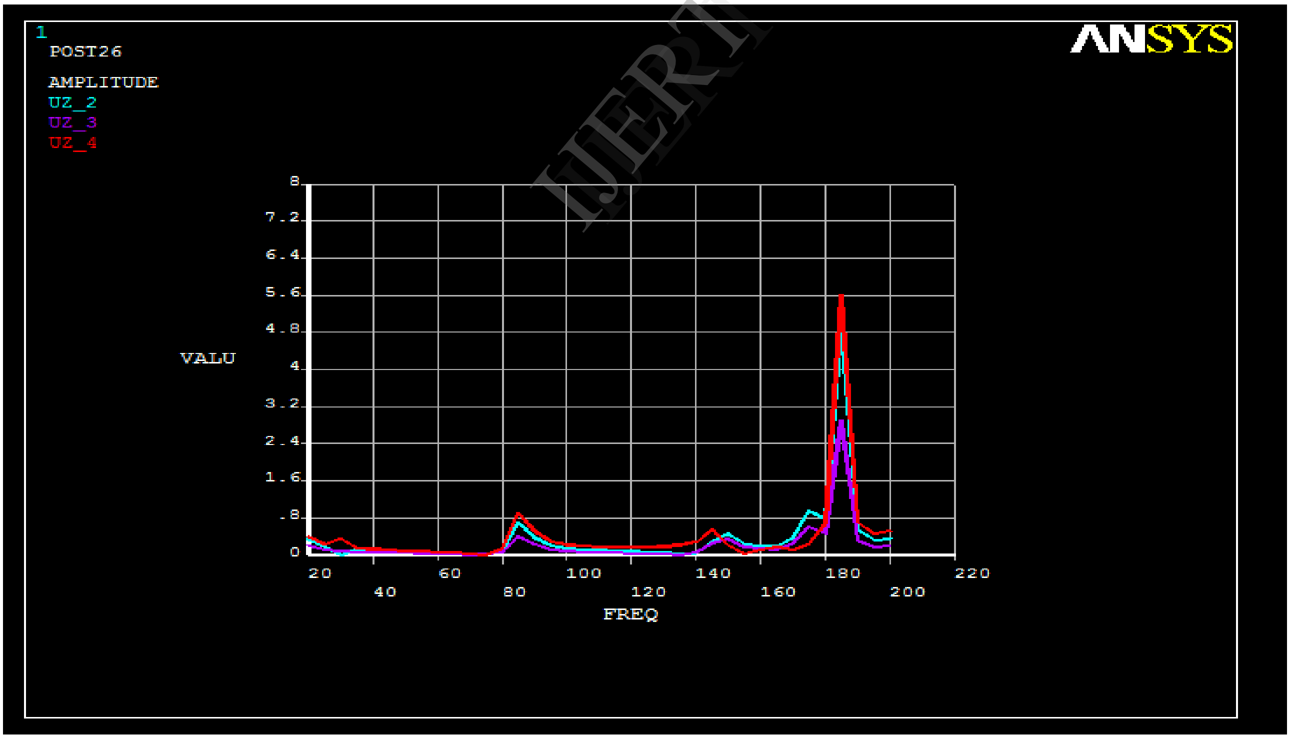


Fig 7. Amplitude in Z-directionwith different nodes Vs. Frequency

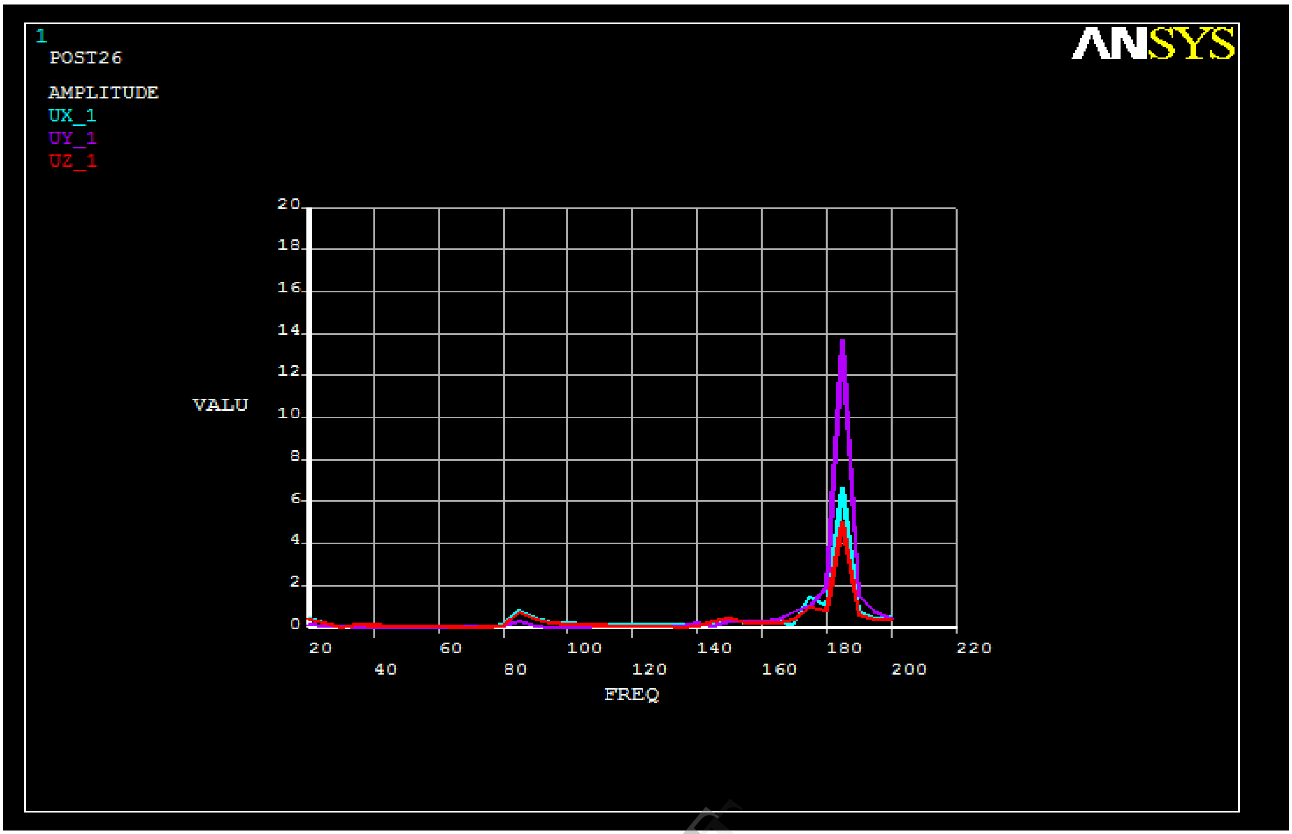


Fig 8: Resultant Amplitude in X, Y, Z direction vs. Frequency

Fig: 9 Proposed vibratory bowl feeder with electromagnets.

RESULT AND DISCUSSION

The experimental results (figure 9) are obtained by using intelligent variable frequency controller with vibration sensor by giving input voltages ranges in between 85V to 260V. The output voltage and output current are ranges in 0V to 260V and 0A to 6A respectively. The vibratory bowl feeder is excited ranging from 40Hz to 400Hz. It operates smoothly at 47.4Hz frequency with 120 V voltages. FEA results show nearly zero amplitude from 40Hz to 60Hz as well as 100Hz to 130Hz frequency range. It is suggest that feeder probably be operated in the range of frequency 40Hz to 60 Hz for effective and economic power consumption. FEA graphs from (fig 5-8) gives the evidence about the results. In this analysis the maximum amplitude is observed at 184Hz (approximately) frequency at which the peak value ofresonance occurs. Therefore, the working of vibratory bowl feeder should be avoided at this frequency. It is clearly observed that the agreement between the finite element analysis and measured result is fairly good. This advocates the efficiency of proposed finite element model for the vibratory bowl feeder.

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