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Vibration Analysis for Bending of Vertical Plates in PVC Scrap Filtration Machine

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***Abstract* - A PVC scrap filtration machine used in VIJAY PLASTIC, Solapur to filter PVC scrap in fine granual by vibrating a bed. The machine vibrates with its leg support i.e. vertical plate which is bend after some instances. This project more focus on static and dynamic analysis of vertical plates of PVC scrap filtration machine. It is necessary to study various loads acting on plates like weight of various components of body, load of PVC scrap which would add to per cycle and the buckling load. Buckling leads to a failure. When a structure is subjected to compressive stress, buckling may occur. It is characterized by a sudden sideways deflection of a structural member. The static load considered for force analysis is not responsible for bending which is calculated and hence it is required to experiment the model for vibration in dynamic body. With the help of ANSYS APDL 19., the stress values of plates due to force acting on plates is obtained and it is found to be safe. There is no any buckling or bending happen in steady condition. There is small deflection after action of compressive load. From static analysis result it can be concluded that buckling of plates occurs due to accelerating condition. So, the next step is dynamic analysis of vertical plate. The project has a great future scope as by investigating the amount of vibration into the system and with the help of dynamic calculation it can be find out the root causes of vibration so that the vibration can be eliminated to maximum extent and thus the life of the system may increase. The future scope of project is to find factors responsible for bending of vertical plate and to modify it as per necessary changes possible with the help of analytical, experimental and finite element analysis technique.**

Index Terms— Stat**ic** analysis, Dynamic analysis, Vibration, Buckling, PVC scrap

I. INTRODUCTION

Albert Einstein once said ‘Everything in life is vibration’ and this quote has an immense importance in our day to day life.

Vibration is basically to and fro motion of a body under or due to the action of external force. Vibration plays an important role in our life as sound is also form of vibration. Law of vibration states that everything in the universe moves and vibrates. Vibration has both positive and negative effects on our daily life as for example random vibration of earth causes earthquake. Vibration also causes formation of racks and deformation of structures and beams [1].

The main objective of this paper is to analyses the bending of vertical plates in PVC scrap filtration machine and to find out the causes of vibration in the plates and to find out a solution to minimize or to reduce these vibrations to minimum extent thus increasing the life of plates thus increasing the productivity of the machine.

PVC scrap filtration machine is a machine which is used to separating the scraps of poly vinyl chloride pipes thus reusing the by-products for different purposes such as for making shoe soles etc. PVC scrap filtration machine consist of sieve of different sizes. Depending upon the size of PVC scrap, the segregation of different product takes place as the scrap passes through sieve of different sizes.

The segregation is done by giving motion to the filtration machine with the help of cam follower arrangement for which 0.5 HP motor is used. S.F machine consist of two pulleys which are connected by V belt. The smaller pulley is mounted on motor shaft and other on camshaft. The

camshaft is got supported by two bearings whose support is connected to rectangular frame. The follower is connected to trolley by fasteners and weld joint. There is no speed variation arrangement for provision made for camshaft.

When we supply feed of scrap powder which do not contain non-magnetic parts to filtration machine, the first compartment gives small piece output which are not able to being pass through the first sieve, these outputs are useful for recycling and is given to pipe making machine. The second compartment gives very fine PVC scrap like talcum powder which sold to shoes manufacturers to make sol of shoes. From third compartment we get sand and dust which is not only use and it is thrown. Scrap Filtration machine is supported by 4 long plates at one side and 2 short plates at other side. Normally plates are used in many engineering applications like aircraft wings, ships, buildings, support, and foundation of footings.

Figure 1. PVC Scrap Filtration Machine

Most of the plate's structures are good at carrying tensile loads but poor in carrying compressive loads. Plates in PVC scrap filtration machine are subjected to loads like weight of various components of body, loads of PVC scrap which is added per cycle and buckling load. Usually buckling phenomenon takes place suddenly and causes structural failure. Therefore, it is important to know buckling capacities of plates to avoid failure of plates.[6] Failure or bending of plates means deflection of plate's perpendicular to plane of plate under the action of external forces and moments. The flexural properties of plate mainly depend upon its thickness, its length and its width.[7]

The failure of a column takes place due to any of the stress's setup in the column i.e. direct compressive stress, buckling stress and combined of direct compressive and buckling stresses. A column is said to be long column if length of column in comparison with its lateral dimension is very large. Such column does not fail in crushing alone but also by bending.[8]

The vertical plate of PVC scrap filtration machine has an end fixed and other is free. The free end will sway sideways when load is applied at free end and curvature in the length will be similar to that of upper half of the column whose both ends are hinged. Due to crippling load column will deflect.

Samer Adeeb [1] investigated the buckling capacity of uniformly compressed flat plates in his study. He categorized material properties based on parameterization of the stress strain curves using a simple and novel mathematical expression.

He concluded that analytical formulations are only suitable for predicting the mechanical behavior of uniformly compressed plates in the elastic range of the material while advanced computational techniques are generally required for achieving a reasonable estimation of the inevitable and complex non linearity's associated with real engineering applications.

In this paper the analysis of vertical plates is done by doing static analysis first i.e.(calculation of various forces acting on the plates) after this dynamic analysis is done by using Ansys software and finite element analysis and thus suggestion has been accordingly.[9]

II. Static Analysis Of PVC Scrap Machine

The frame of PVC scrap filtration machine placed on 6 vertical rectangular mild steel plates, two plates at one end and 4 plates at another end. Frame makes 30-degree angle with horizontal. After periodic use of PVC scrap filtration machine supporting plates tends to bend. When load on plate goes beyond critical load buckling of plates occurs. Plates tend to bend when continuous in working condition over period of times. Plate material is mild steel which is ductile material. First of all, it subjected to static load hence bends and in accelerating condition for long duration it buckles.[3]

The total load acting on the body is 1156.36N which is distributed in both the side is equal.

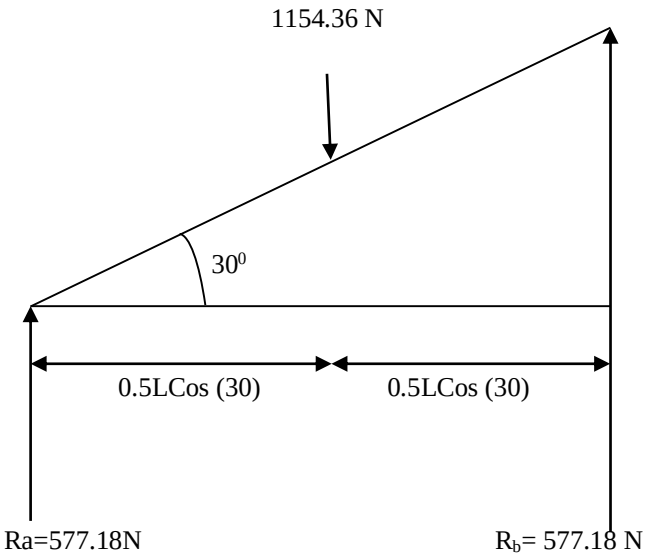

Figure 2. Free body diagram

In equilibrium condition,[4]

$\Sigma M_A=0$

$R_A \times 1.95\cos 30 - 1154.36*0.5*1.95\cos 30=0$

$R_A=577.18$ N

$R_B=1154.36-577.18=577.18$ N

Reaction of both sides are

$R_A=577.18$N

$R_B=577.18$N

After getting exact weight acts on every single plate, the next step is to check whether plates bear that weights or not without failure. So, it has to find out critical load acting on each plate. If critical load is smaller than actual weight act on plate then it is clear that plate buckle at static condition.

A. Critical load

The critical load is the maximum load [5] which a column can bear while staying straight. It is given by the formula [13].

$$F_{cr}=\pi^2 EI / L^2$$

Where,

F_{cr} = Euler's critical load (longitudinal compression load on column),

E = modulus of elasticity of column material,

I= minimum area moment of inertia of the cross section of the column,

L = column effective length factor

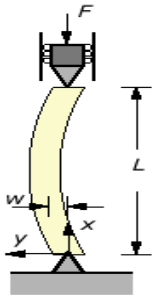

Figure 3. critical load on vertical column [14].

TABLE 1

CRITICAL LOADS ON PLATES

Sr. No.	Plate	Critical load
1	Short	355.7360 N
2	Long	192.6645 N

From table 1 we can conclude that the load acting on plates is less than critical load.

R_A and $R_B < F_{cr}$

Hence, plates are not buckling at static condition.

III. DYNAMIC ANALYSIS OF PVC SCRAP FILTRATION MACHINE

3.1. Analytical Analysis

After getting safe results in static analysis, next step is dynamic analysis. Here machine is in working. The effect of to and fro motion of plates will get at the end of dynamic analysis. Dynamic or vibration considerations are often overlooked during design, resulting in vibration as a common failure mode across a wide range of products and applications

There are some consideration has to take during dynamic analysis such as

1) Weights are equally distributing over plates.
2) Plates only have lateral motion in the direction of follower.
3) Plate consider as cantilever beam

The stiffness for a cantilever beam [11] is,

$$k = 3EI / L^3$$

Where,

E = elastic modulus (200GPa)

I = second moment of area about the neutral axis

= 5.2*10^-8 m^4

L = length of the member

TABLE 2

STIFFNESS OF PLATES

Sr. No.	Plate	Stiffness
1	Short	101.6079 KN/m
2	Long	87.651 KN/m

Therefore, the equivalent stiffness is

K_{eq} =189.258 KN/m

Natural frequency of plates is

$$f_n = 1/T = (1/2\pi)\sqrt{(k/m)}$$

F_n=7.995 Hz

TABLE 3

PARAMETER VALUES OF PLATE

Parameters	Outer long plate	Inner Long Plate	Short Plate
Resonance	5.9 Hz (2. e+2), 44 Hz (1.9e+2)	29 Hz (5.1e+2), 5.8 Hz (1.9e+2)	5.9 Hz (1.4e+2), 45 Hz (1.4e+2)
RMS Vibration	13	14	8.3

Based on the natural frequency of system which is 7.98 Hz, the amplitudes of displacement, velocity and acceleration are calculated by using analytical method. It is necessary to verify this analytical result by experimental and finite element analysis. By comparing analytical results, FEA results and Experimental results the ultimate result and conclusion can be found out.

3.2 Experimental Analysis

The machine does not fail under static forces. Hence amplitude of the system is verified by vibration analysis using FFT analyzer. In this the readings are taken on FFT (Fast Fourier Transform) and Vibration acceleration, Power Spectrum densities are observed [12].

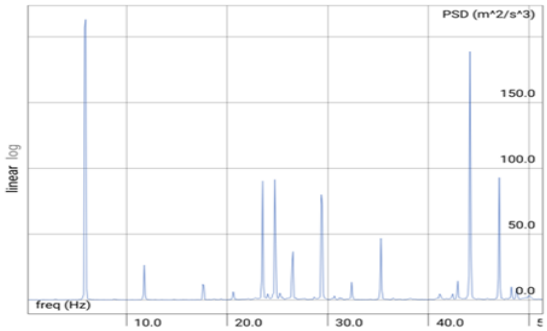

Figure 4. Power Spectrum of outer long plate

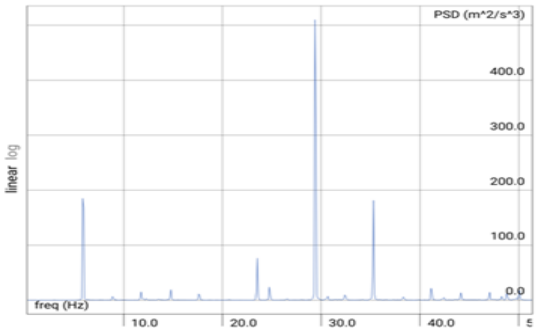

Figure 5. Power Spectrum of inner long plate

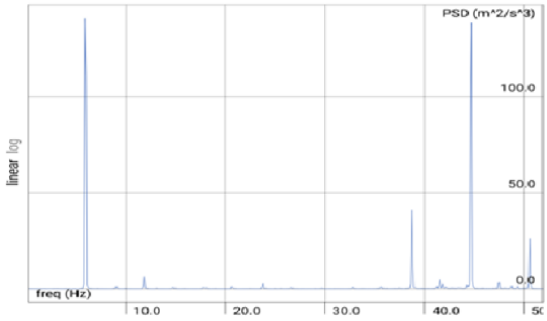

Figure 6. Power spectrum of short plate

TABLE 4

RESULTS OF FFT

Natural Frequency	Displacement amplitude	velocity amplitude	acceleration amplitude
7.98	13.3060	0.1516	18.9114

The results of graphs are tabulated in above table. For further procedure the dynamic analysis of system is to be verified by using Finite Element Analysis (FEA).

3.3 Finite element analysis

Consider a vertiacal plate as spring.make model which volume same as a volume of a system.material use is mild steel.spring attachement is consider here. that plot the harmonic response.in this case amplitude is very high which is damaged the system [10].

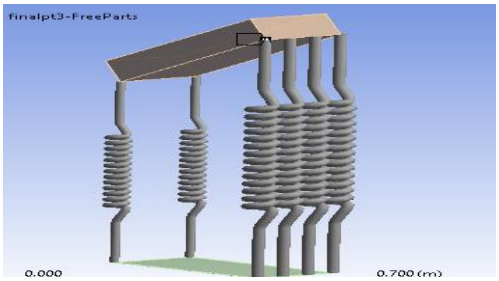

Figure 7. Mass Spring Arrangement[2]

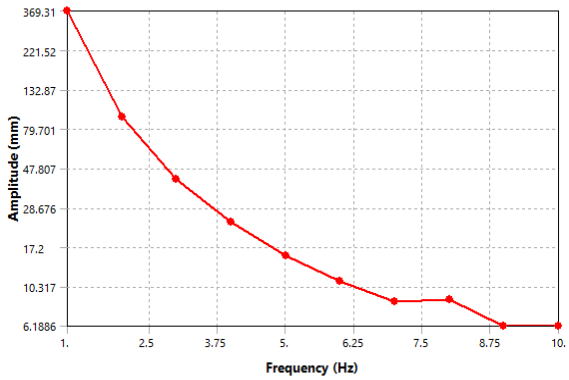

Figure 8. Harmonic response of Amplitude vs Frequency

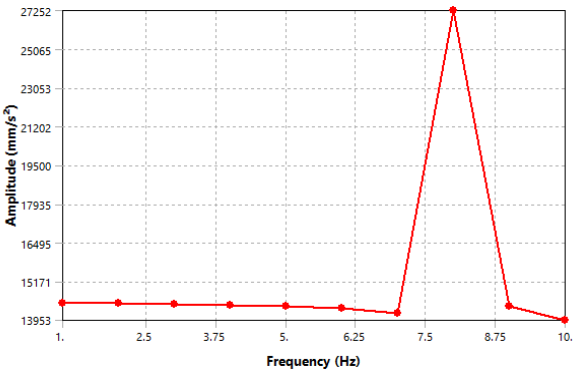

Figure 9. Harmonic response of Frequency vs. acceleration

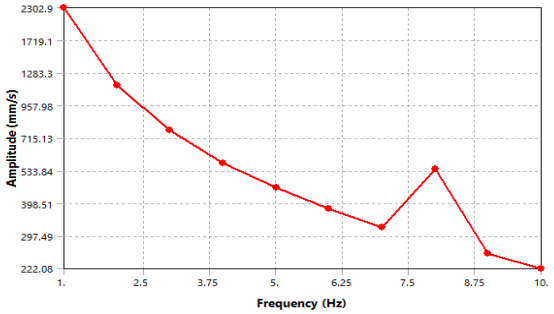

Figure 10. Harmonic response of Frequency vs. Velocity

After Ploting result its found that amplitude is very hige.to reduce the amplitude the need of change in plate length and increase stiffness of vertical plate.

IV. Results

The amplitude of the vibration is high. So, to decrease the amplitude of vibration stiffness of the plates should be high. Stiffness of the plate is depending on length and cross-section of plate. As length of plate decreases stiffness of the plate increases. Length and stiffness are inversely proportional to each other.

TABLE 5

ANALYTICAL RESULT

Sr. No.	Length of short plate (m)	Length of large plate (m)	Equivalent stiffness (KN/m)	Natural frequency (Hz)	Amplitude (mm)	Velocity (m/s)	Acceleration (m/s²)
1	0.85	1.155	189.258	7.99	13.3064	0.5016	18.9194
2	0.784	0.98	195.78	8.137	12.58	0.4777	18.132
3	0.768	0.96	208.28	8.3871	10.99	0.4169	15.868
4	0.75	0.95	220.28	8.633	9.7819	0.3716	14.117
5	0.752	0.94	221.86	8.6562	9.681	0.3677	13.9714
6	0.736	0.92	236.64	8.94	8.566	0.3254	12.363
7	0.7	0.9	267.51	9.505	6.8	0.257	9.738

TABLE 6

FEA RESULT

Sr. No.	Length of short plate (m)	Length of large plate (m)	Equivalent stiffness (KN/m)	Natural frequency (Hz)	Amplitude (mm)	Velocity (m/s)	Acceleration (m/s2)
1	0.85	1.155	189.258	5	12.943	0.406	17.92
2	0.784	0.98	195.78	5.28	11.16	0.377	17.02
3	0.768	0.96	208.28	5.38	11.96	0.35	14.78
4	0.75	0.95	220.28	6.25	8.28	0.325	13.52
5	0.752	0.94	221.86	6.42	7.829	0.316	12.65
6	0.736	0.92	236.64	8.66	5.45	0.254	11.42
7	0.7	0.9	267.51	9.22	5.02	0.22	10.47

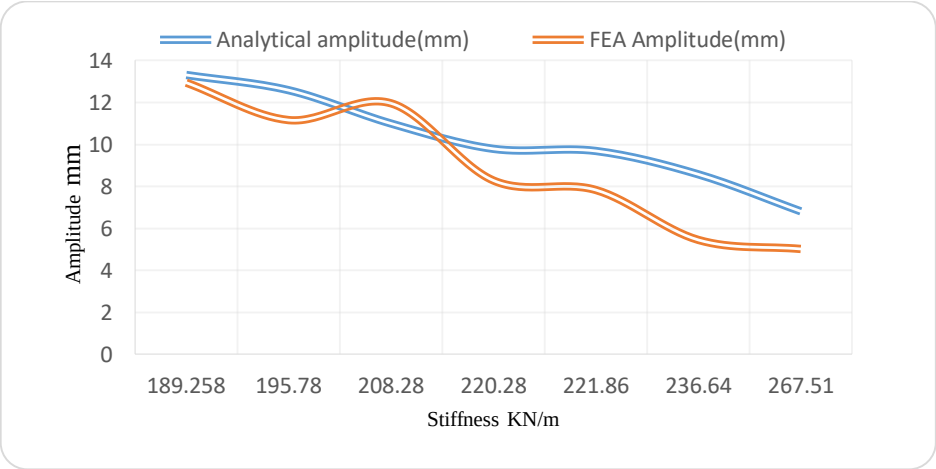

Figure 11. Stiffness vs Amplitude

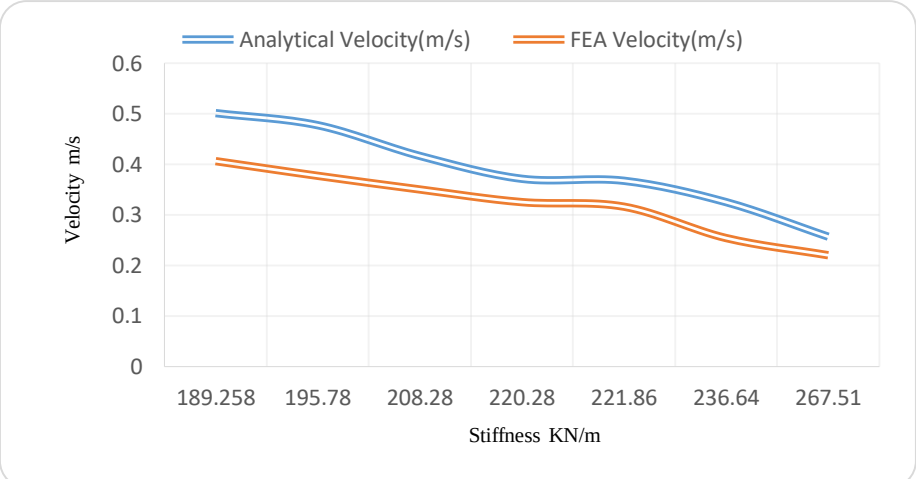

Figure 12. Stiffness vs. Velocity

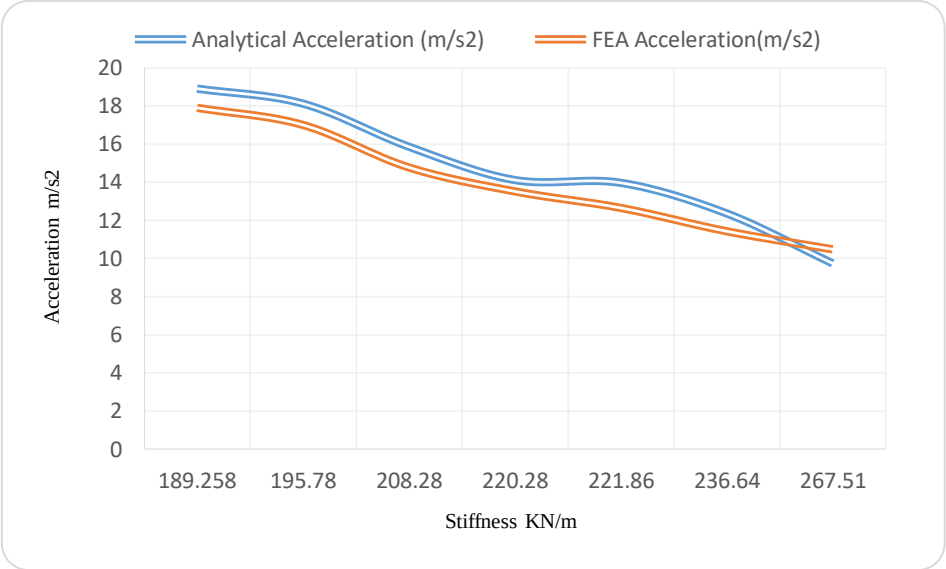

Figure 13. Stiffness vs. Acceleration

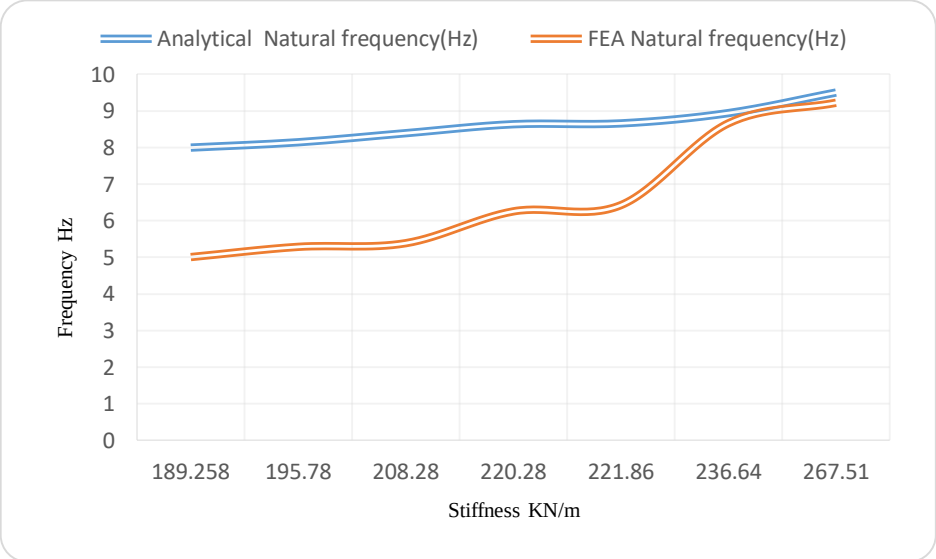

Figure 14. Stiffness vs. Frequency

As stiffness increases, the amplitude decreases in both analytical and Finite Element Analysis as shown in figure 11. As stiffness increases, the velocity decreases in both analytical and Finite Element Analysis as shown in figure 12. As stiffness increases the acceleration in analytical analysis decreases as shown in figure 13. Both parameters are inversely proportional to each other. As stiffness increases, the natural frequency of system increases as shown in figure (14). Stiffness and natural frequency are directly proportional to each other.

CONCLUSION

To find the bending of vertical plates of PVC scrap machine various analysis has been carried out and based on the analysis it is conclude that,

1. The plate is considered as column and is not bending at static condition. The maximum stress induced in plate is 30.29 MPa which is less than yield strength of material.
2. Hence it was required to proceed for dynamic analysis by considering single degree of freedom system where the natural frequency is obtained as 7.99 Hz. The

displacement, velocity and acceleration amplitude are obtained as 13.30 mm, 0.15 m/s and 18.91m/s ^{2} respectively.

3. An analytical results are verified using experimental analysis over plate using FFT analyzer where maximum amplitude of acceleration is obtained as 14 m/s^2 at 29 Hz. Hence it is verified that the peak value is obtained at 6 Hz for all three cases considered.
4. Also, finite element analysis is used to verify analytical and experimental results and harmonic analysis reveals that an acceleration 14.5 m/s^2 is nearly matches with analytical and experimental results.
5. From overall analysis it is observed that the amplitude of vibration is system is more and hence it is required to reduce it. Therefore, modifications are suggested to reduce amplitude by increasing stiffness of plate.
6. It has been observed that by increasing stiffness of plates the vibration amplitudes are continuously decreases from 18m/s^2 to 9m/s^2. Therefore, it is concluded that the stiffness of plates are required to change to reduce vibration in machine and it is recommended to Vijay Plastics Industries, Solapur.

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