Design and Optimization of Wooden Plank used in Vibratory Conveyor

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***Abstract*: Vibratory conveyors are used to convey a wide variety of material ranging from dry powders to heavy block casting etc. These conveyors are used for screening, drying, cooling with conveying. Design of major component of vibratory conveyor is designed precisely, so it won't affect its operational performance. Design of supporting element is very important aspect like wooden planks in present case. If supporting element is not designed properly, then it will fail to operate critical operations in the system. Therefore supporting element needs to be designed for high strength, excellent fatigue properties and for optimum stiffness. In the present project work, brief failure analysis of currently used supporting member is done. Accordingly another material is being suggested which can replace current member, without failing to perform its operation, such as fiberglass reinforced plastic(FRP). The prototype of the same is done and tested with standard procedure. 3D Modeling of all components are created using CATIA V5 R19 software and analysis is done in ANSYS 14.5.**

***Keywords* — Vibratory conveyor, FiberglassReinforced Plastic, fatigue, optimization.**

INTRODUCTION

Design and development is nothing but design of system according to customer requirement and purpose of use. The frequent failure of wooden planks degrades the performance of vibrating conveyor. To avoid these problems, another material having more life than pine wood should be used. Also to check performance of new material and other parameters, a prototype model of vibrating conveyor is built. There are many materials available, which can replace pine wood. FRP is selected as replacement for pine wood due its inherent properties.

High strength, cured, fiberglass reinforced plastic material was first introduced for use of vibratory conveyor springs in 1954. Since then, fiberglass springs have been used successfullyin a wide range of vibratory conveyors, feeders and screening equipment, providing infinite fatigue life and corrosion free service.

These springs are made of 3M's Scotch ply brand reinforced plastic, a unique material in which the epoxy resins are reinforced with continuous, linearly aligned, non-woven filaments. It allows the plies to be laid up so that the reinforcement is oriented to the greater strength and stiffness in the direction in which it is most needed [6].

I. WORKING PRINCIPLE

The vibrating conveyor has lengthy trough supported by hinged legs from base member, as a parallelogram arrangement. The arrangement remains stable by additional spring supports. The steel trough is oscillated / moved by crank mechanism throw, and accordingly its amplitude of motion (vibration) has fixed value irrespective of speed [2]. The crank mechanism direction of action is set such that it results into forward as well as upward stroke for trough, to create material movement [5].

The purpose of FRP planks is to provide auxiliary support as well as to store gravitational energy during downward movement, and to release it during upward stroke against gravity, and thereby smaller drive and economical conveyor. Also spring system size and stiffness are chosen so that the system natural frequency is close to operational frequency, to avoid its hindrance to drive action.

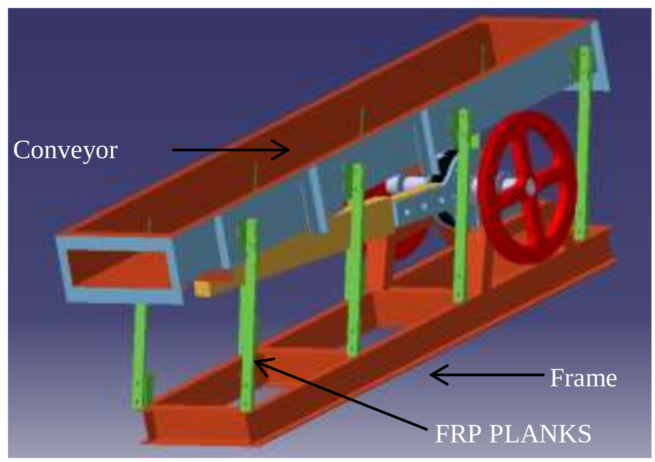

Fig. 1: Principle of vibratory Conveyor

Fig 1 shows a CATIA model of 2000mm x 500 mm actual prototype. Drawing of model is done in CATIA V5 R19. First 3D drawings of all the components are drawn in part design with calculated design dimensions. Then all the components are imported in assembly section. And assembly of all the components is done as per the actual hopper. To draw current prototype model, bottom up approach is used.

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II. EXPERIMENTAL SETUP

Fig 2: Experimental Setup of Vibratory conveyor

III. Design calculation

Table 1: Prototype Specifications

Sr. No.	Parameter	Value
1	Belt design power	3.13kw
2	Belt cross section	A-Type
3	Smaller pulley diameter	85mm
4	Larger pulley diameter	420mm
5	Belt pitch length	2050mm
6	Center distance	610mm
7	No of belts	2 nos
8	Mass moment of interia	0.27kg.m^2
9	Self-align ball bearing	2211K,H311
10	Spherical roller bearing	22218K,H318
11	Shaft diameter	50mm

Sr.no	Properties	Direction	G10 FR4
1	Tensile strength	length wise	275 MPa
		Cross wise	241.31 MPa
2	Compressive strength	Flat wise	413.68 MPa
		Edge wise	241.31 MPa
3	Flexural strength	Length wise	380 MPa
		Cross wise	310 MPa
4	Modulus of Elasticity in flex	Lengthwise	18615.84 MPa
		Crosswise	15168.46 MPa
5	Shear strength	-	131 MPa

Table 2:Properties of G10 FR4 Material

IV. Vibration Analysis of Prototype

Vibration analysis on hopper of size 2m X 0.5m is performed. Displacements, velocity, acceleration reading on bearing pedestal & at top portion of FRP flank are taken. Also acceleration readings on front, middle and end of tray section are taken by using FFT analyzer. Hopper was running on 3hp induction motor at speed of 290rpm.

Table 3: Vibration Reading On Prototype

Pick up position	Vibration Parameter	
	Vel,mm/s	Acc.m/s2
Backside of hopper	323	1.08
Middle of hopper	317	1.1
Front side of hopper	314	1.08
FRP front side	335	1.15
FRP Back side	335	1.15

Table 4: Vibration reading at Bearing Pedestal on Prototype

Bearing location	Pick up position	Vibration parameters		
		Dis.microns	Vel.mm/s	Acc.m/s2
DE (Plane 1)	H	176	5.99	0.037
	V	203	2.13	0.038
	A	189	1.3	0.03
NDE (Plane 2)	H	216	7.27	0.039
	V	593	3.12	0.13
	A	24	1.27	0.032

Velocity and acceleration of prototype at different locations is measured. Acceleration readings on prototype do not show much variation in the readings as given in Table 3. Also velocity and acceleration values on FRP at its free end are measured. Vibration readings at bearing pedestal are measured afterwards. Table 4 shows displacement, velocity and acceleration readings on drive end (DE) and on non-drive end (NDE). After observing velocity values at NDE and DE it showed some problems in the system like alignment problem, unbalance in the system. If the

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foundation of prototype is considered, it is not properly rigid. Therefore system vibrates more as compared to rigid foundation system. Vibration level shows variation velocity parameter in horizontal direction.

FFT Spectrum of Prototype

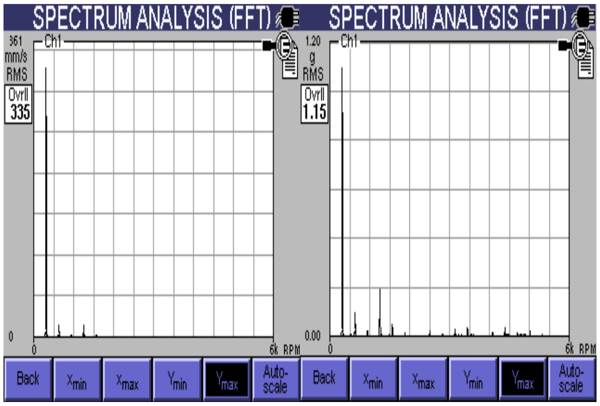


Figure 3 Vel, Acc, Measurement on FRP Front Side of Prototype

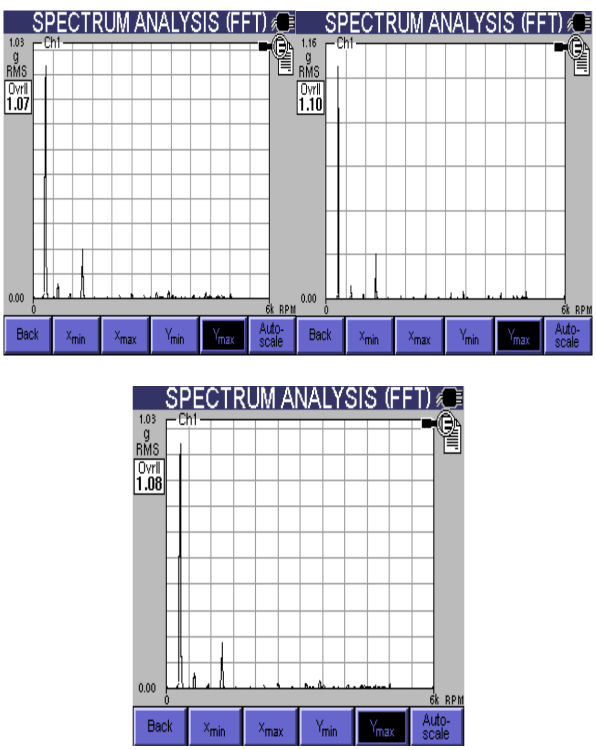


Figure 4: Acc of Prototype at Front, Middle, End of Hopper.

Vibration analysis of prototype reading is shown in fig 3. The disp, vel, acc parameter on FRP are measured; also the acceleration of prototype at various positions is measured. And spectrum analysis prototype is as shown in fig 4. Acceleration of prototype measured was also almost same as acceleration of actual hopper. All the measured parameters are within the acceptable limit.

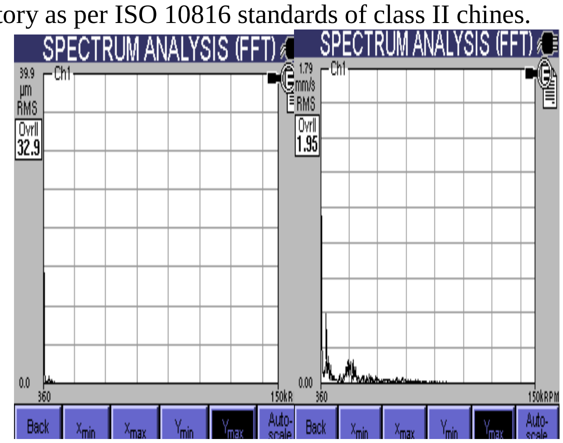
V. Vibration Analysis Of 12m X 2m Hopper

Any physical system can vibrate. The frequencies at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using Modal Analysis. Inherent vibration modes in structural components or mechanical support systems can shorten equipment life, and cause premature or completely unanticipated failure, often resulting in hazardous situations. Detailed fatigue analysis is often required to assess the potential for failure or damage resulting from the rapid stress cycles of vibration. Vibration analysis can help us to detect a wide variety of fault conditions such bearing failure, imbalance in system etc. As the shaft turns, there are frictional and rotational forces. That vibration created by those forces is transferred via the bearings to the machine housing. For vibration analysis purpose, study of vibratory motion was carried out using FFT analyzer.

a FFT Spectrum For 12m X 2 M Hopper

A fast Fourier transform (FFT) is an algorithm to compute the discrete Fourier transform (DFT) and it's inverse. Fourier analysis converts time (or space) to frequency (or wavenumber) and vice versa; an FFT rapidly computes such transformations by factorizing the DFT matrix into a product of sparse (mostly zero) factors. As a result, fast Fourier transforms are widely used for many applications in engineering, science, and mathematics. We have performed vibration analysis on 2m width hopper in which an accelerometer was attached at the end of the wooden plank to measure the displacement, velocity and acceleration due to vibration. Accelerometer converted the mechanical motion signal into the electrical signal which was fed to the FFT analyzer. From fig 5 and 6 itsshows result of vibration measurement at NDE and DE end at bearing pedestal.

ISO 2372 (10816) Standards provide guidance for evaluating vibration severity in machines operating in the 10 to 200 Hz (600 to 12,000 RPM) frequency range. Graph in fig 5 and 6 shows velocity values measured are satisfactory as per ISO 10816 standards of class II chines.



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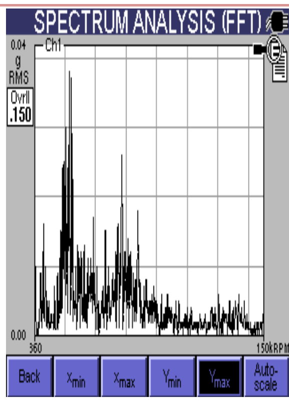

Figure 5: Disp, vel, acc in Horizontal Direction on NDE

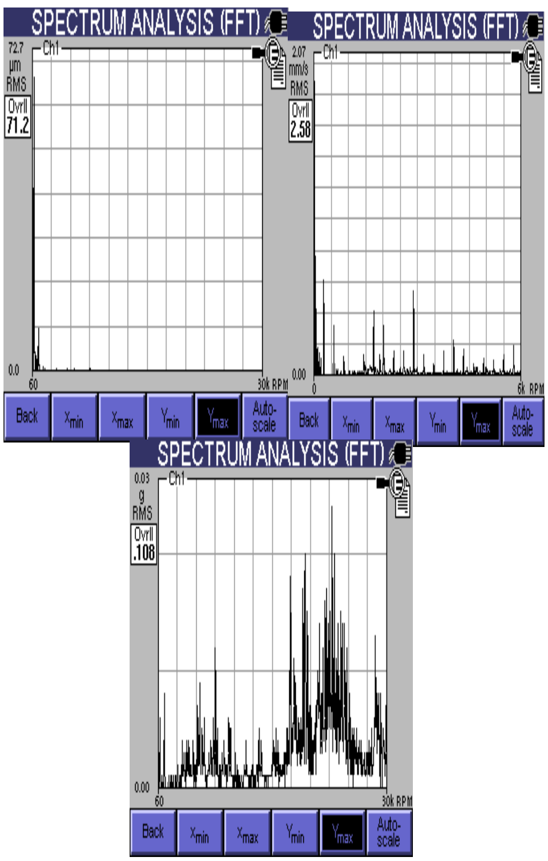

Figure 6: Disp, vel, acc in Horizontal Direction on NDE

We also measured vibrations at the end of wooden plank assembly and at the middle section of wooden plank assembly of 2m width of hopper. Our main purpose is finding out how the wooden plank behaves during working condition. For that we measures velocity and phase angle between wooden planks as shown in fig 7. Fig shows that when load is increased on hopper middle section of wooden strips moves outward and creates mode shape which develops uneven vibration in the wooden plank assembly. Wooden strips moves in outward direction, creates convex shape as shown fig 7. If angle between these wooden strips is out of phase, then generation ofmode shapes due these strips develops uneven stress in the plank assembly.

Figure 7: Measurement of Phase angle on Wooden Plank

For measurement of velocity and phase angle accelerometer was connected to the wooden strip at the middle location. Velocity and phase angle were measured for two different locations, the result of which are shown in following table 3-3

Table 5: Velocity and Phase Angle at Middle Section of Plank

Location	Velocity (mm/s)	Phase angle
1	171	70◦
2	177	250◦

The detailed study of above results depicts that there are no serious issues present in the system at the end points of the wooden planks which will cause it to fail prematurely, since the acceleration, velocity and displacement graphs do not have any kind of variance. But the phase angle measurement results show serious issue.

VI. CONCLUSION

1. The wooden plank was observed to fail due to different mode shapes occurring in steel and wood due to system generated vibrations. Apart from knots present in the pine wood, fiber orientation etc. failure due to mode shapes is also most prominent cause of wooden plank assembly.
2. FFT result analysis on Existing hopper and prototype shows lower limit of vibration level. Also it is seen, the acceleration of vibrating conveyor increases from 0.98 m/s2 to 1.15 m/s2 when FRP is used as supporting element. Due to this screening rate of hopper is increased.
3. Though FRP is having higher cost as compared to the wood, the excessive cost gets the justification because of the cost saved by FRP by not allowing

the system to fail. This eliminates about 50% to 60% of production loss.

4. A prototype was built on the basis of measurements taken from actual hopper system so as to carry out different tests on the prototype which are required to be conducted on the actual system such as alignment test. Alignment test was proved positive which eliminates various other problems like lateral motion of hopper, failure of main bearings.
5. Alignment test performed on prototype shows better stability of the vibrating conveyor, when material used as supporting element is FRP.
6. Due to some inherent properties of FRP, it has a capability to store certain amount of energy which is released and stored repetitively during the cycle of operation. Amount of energy storage in FRP is 1.8 pine wood. This reduced the power consumption of the system allowingusing a motor with lower capacity.

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