Experimental & Finite Element Analysis of Pine Wood Used In Vibratory Conveyor

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ABSTRACT

To convey material from one place to another different conveyor systems are available in industries, such as belt conveyor, chain conveyor, vibratory conveyor etc. Considering the application of sorting, lumping, screening, drying, vibratory conveyors are used to serve the purpose. Most of the vibratory conveyor use pine wood as its material for supporting element (planks). Pine wood has advantages over regular wood like high strength to weight ratio, good shock resistance & insulating property against heat, sound& electricity. Also pine wood is more dimensionally stable compared to regular wood. To find out causes of failure of supporting element of vibratory conveyor, experimental & finite element analysis of pine wood is important in present case.

Keyword: *- Vibratory conveyor, pine wood, supporting element, finite element analysis.*

1. INTRODUCTION

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Many kinds of conveying systems are available, and are used according to the various needs of different industries such as sugar industry.

In the process of sugar manufacturing, vibrating conveyors are being used for sorting a sugar lump from sugar flow. Wood strips are used to support the system and transmitting a motion to conveyor. During this process strips (planks) are subjected to cyclic loading, resulting in a failure of strips after certain no of load cycles. It also increases power consumption and breakdown time.

2. LITERATURE REVIEW

G.Winkler [3] carried a research on vibrating conveyor which consists of a track that oscillates in a straight line inclined with respect to horizontal, but does not have any net motion. Particles placed on the track advance because of variation in normal and friction forces during the forward and downward strokes. Author studied the conveyor with inclined motion has been shown in fig 2.1, to combine simplicity of design with high performance in terms of the mean transport velocity for a given track velocity amplitude. In general, the performance of this design has been shown to improve as amplitude of vertical track acceleration was increased.

Also how the study of impact velocity leads to increase wear and noise in hopping conveyor is explained by non-dimensional analytical prediction of the performance of vibrating conveyor with triangular track motion, first developed for sliding conveyor and showed results are suitable for hopping conveying.

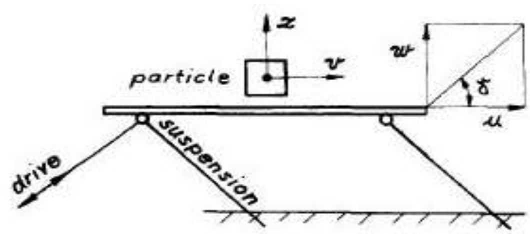

Figure Error! No text of specified style in document.**-1***:* Vibrating Conveyor with Inclined Motion of Horizontal Track

Rakesh Hota et al [4] Physical testing was carried out for two different samples 60% epoxy 40% E- fiberglass, both prepared in the laboratory. The study gave a comparative analysis between the composite leaf spring and steel leaf spring based on physical properties.

Various test were performed on these two composition such tensile test, impact test, and analysis also carried on both the composition. Test results showed that use of composite leaf spring having 50% of epoxy and E-glass fiber gave weight reduction of 88.95% as compared to steel spring. Also fatigue life, natural frequency parameters were compared and in that two composition of 60% epoxy + 40% E-glass was found to be better than 50% epoxy + 40% E-glass fiber.

M.A. Parameswaran et al [5] have given contribution to understand the phenomenon of vibratory conveying and scope for work on dynamic and design aspects of vibratory conveyor, and the principle of vibratory conveyor and different type's mechanisms for vibratory conveyor. The study of vibrating systems, drives, and mechanics of conveying was carried. The use of helical compression springs and hollow rubber springs allows large spring and reducing force transmitted to foundation. They also derived expression for determining power for vibrating conveyor but do not give a readily usable expression.

G.L.Hinueber [6] has carried out research on flat leaf spring used in vibratory conveyors and other vibratory equipment which are subjected to high bending forces in single plane. Also he has given the design process for fiberglass reinforced plastic used in vibratory conveyor and stress analysis of fiberglass flat leaf spring. In the design of supporting structure, stiffness of supporting structure is very important aspect. Design process for finding stiffness of leaf spring for vibrating conveyor is given.

3. STUDY OF PINE WOOD PROPERTIES

1 **Modulus of rupture** = Reflects the maximum load-carrying capacity of a member in bending and is proportional to maximum moment borne by the specimen. Modulus of rupture is an accepted criterion of strength, although it is not a true stress because the formula by which it is computed is valid only in the elastic limit [13].

2 **Work to maximum load ratio in bending** = Ability to absorb shock with some permanent deformation and more or less injury to a specimen. Work to maximum load is a measure of the combined strength and toughness of wood under bending stresses.

3 **Compressive strength parallel to grain** = Maximum stress sustained by a compression parallel-to-grain specimen having a ratio of length to least dimension of less than 11.

4 **Compressive stress perpendicular to grain** = Reported as stress at proportional limit. There is no clearly defined ultimate stress for this property.

5 **Shear strength parallel to grain** = Ability to resist internal slipping of one part upon another along the grain. Values presented are average strength in radial and tangential shear planes.

6 **Impact bending** = In the impact bending test, a hammer of given weight is dropped upon a beam from successively increased heights until rupture occurs or the beam deflects 152 mm or more. The height of the maximum drop, or the drop that causes failure, is a comparative value that represents the ability of wood to absorb shocks that cause stresses beyond the proportional limit.

7 **Tensile strength perpendicular to grain** = Resistance of wood to forces acting across the grains that tend to split a member. Values presented are the average of radial and tangential observations.

8 **Hardness** = It is defined as resistance to indentation using a modified Janka hardness test, measured by the load required to embed an 11.28-mm ball to one-half its diameter. Values presented are the average of radial and tangential penetrations.

9 **Tensile strength parallel to grain** = Maximum tensile stress sustained in direction parallel to grain.

4. BENDING TEST AND STIFFNESS MEASUREMENT OF WOODEN PLANK

There are two methods to find out stiffness of wooden plank by experimentally and by fundamental equations. In present case, the stiffness of wooden plank was found experimentally. By applying different weights at one end of the wooden plank, measure the deflection at particular weights.

4.1 Three Point Bend Test

The width (w) and height (h) of wood samples are measured, and the specimens are placed in a three-point bend testing apparatus with the height of the wood oriented vertically in the apparatus. The distance (L) between the two supports is also measured. The deflection at the middle of the beam, as a function of load on the pan of the apparatus, is measured to calculate the stiffness. As the elastic properties of wood are being tested it is important to ensure that the sample does not become permanently deformed. To achieve this, the mass on the pan is increased stepwise in 25 kg increment.

Bending test is carried out on standard wooden plank specimen use in vibratory conveyor at different loads. By using three point symmetric bending test, we can find deflection of beam [6].

$$\delta = (mgL\char`^3)/48EI \quad \text{------------------} \quad (4.1)$$

The Young's modulus for sample is calculated from:

$$E = \left(\frac{gL^3}{48I}\right)\left(\frac{m}{\delta}\right)$$

Table 4-1: Bending Test Result

TARAPURWALA BENDING TEST MACHINE

TEST RESULTS	**Specimen Size=800x65x26mm**

SR NO	Load(N)	Deflection(mm)	Stiffness(N/mm)	Average Stiffness(N/mm)
1	250	6	**41.66**	**43.18**
2	500	11	**45.45**	
3	750	17	**44.11**	
4	1000	20	**50**	
5	1250	30	**41.66**	
6	1375	38	**36.18**	

Bending test on wooden plank assembly is performed. Above table gives a stiffness of wooden plank assembly. That is almost equal to the stiffness calculated by applying different size of weight at one end of wooden plank assembly. Load v/s deflection graph is also plotted. From fig 4-1 show that as load increases deflection of wooden plank also increases linearly up to certain load value. After increasing load further brittle type failure occurs without any warring.

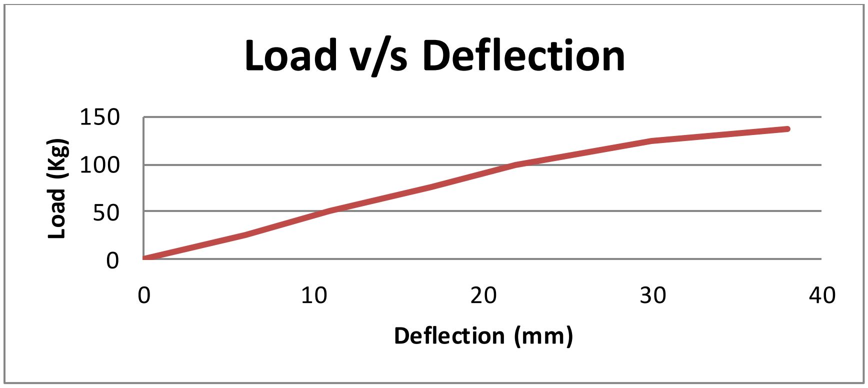

Figure 4-1: Load v/s Deflection Graph

4.2 Causes of Wooden Plank Failure

Clear straight-grained wood is used for determining fundamental mechanical properties; however, because of natural growth characteristics of trees, wood products vary in specific gravity, may contain cross grain, or may have knots and localized slope of grain. Natural defects such as pitch pockets may occur as a result of biological or climatic elements influencing the living tree. These wood characteristics must be taken into account in assessing actual properties or estimating actual performance of wood products [13]. Failure of wood due to knot present in wood, due to tension, slope of grains and bending are possible.

4.2.1 Knots

A knot is that portion of a branch that has become incorporated in the bowl of a tree. The influence of a knot on the mechanical properties of a wood member is due to the interruption of continuity and change in the direction of wood fibers [13].

Knots are further classified as Intergrown or encased as shown in fig 4.2.1. As long as a limb remains alive, there is continuous growth at the junction of the limb and the bole of the tree, and the resulting knot is called Intergrown. After the branch has died, additional growth on the trunk encloses the dead limb, resulting in an encased knot; bole fibers are not continuous with the fibers of the encased knot. Encased knots and knotholes tend to be accompanied by less cross grain than are inter-grown knots and are therefore generally less problematic with regard to most mechanical properties [13].

Figure 4.2.1: Flaws in Wooden Plank

Most mechanical properties are lower in sections containing knots than in clear straight-grained wood because,
(a) The clear wood is displaced by the knot,
(b) The fibers around the knot are distorted, resulting in cross grain,
(c) The discontinuity of wood fiber leads to stress concentrations, and
(d) Checking often occurs around the knots during drying. Hardness and strength in compression perpendicular to the grain

4.2.2 Tension

Almost pure longitudinal tension occurs in the pulled members of the wooden plank. Wooden planks are solicited by tension and bending due to force transmitted by drive. The failure to longitudinal tension should lead to a progressive rupture of the fibres, not necessarily positioned in the same transversal section, at an accelerated pace because the section gets smaller and smaller [10]. But it is very difficult indeed to take hold of the extremities of the member in a totally efficient way and what generally happens is that the material gives way at the abutment of the joint and the tension vanishes.

A quite specific failure mode is to be considered, which, is the longitudinal break of the extremity of a member where a pin or nail is inserted. The wood divides along the fibres, in other words it splits, and the holding device slides along the borders of the split thus allowing the tension to release as shown in figure 4.2.2.

Figure 4.2.2: Failure Cause by Tension in Wooden Flank Assembly

4.2.3 Bending

Predominantly, breaks of the members are caused by bending moments. After the first phase of deformation, the break generally occurs to tension at the intrados caused by the presence of knots and possibly other defects or damages (made by fungi, wrong working etc.). When the tensions induced by loading are bigger than the rupture strength to compression but, at the same time, lower than to tension, it is constituted by a first phase of bulging and longitudinal cracking of the compressed regions at the extrados followed by the increase of the tensile strain and consequently the crack at the intrados due to tension as shown in figure 4.2.3.

 

Figure 4.2.3: Wooden Plank-Before and After Failure

4.2.4 Failure of The Connection

Amongst the main causes of discontinuity of the joints we caught to remember the effects of swelling and shrinkage produced by the fluctuations of temperature and humidity, the ageing of the adhesives, the defects and the biotic damage of the wood, the corrosion of the metallic fastenings, the inadequacies of the design and occasional factors. At the more general level, the effects are reduction of the abutment surfaces and consequent concentration of the stresses on small areas, eccentricity of the stresses, widening of the encasement with occurrence of clearances as shown in figure 4.2.4.

Irregularities of the grain of one ruler ending in one joint turns to be very dangerous for the life of the connection because the affected member, when in place and solicited, is soon twisted by torsion with the consequence of tensions acting not along the main axis but in a different direction, to which the joint is not suitable and wood less strong.

Figure 4.2.4: Crack Prorogated near Discontinuity of Wood Plank

4.2.5 Slope of Grain

In some wood product applications, the directions of important stresses may not coincide with the natural axes of fiber orientation in the wood. This may occur by choice in design, from the way the wood was removed from the log, or because of grain irregularities that occurred while the tree was growing.

4.3 Dynamic Response Analysis of Wooden Plank

To find out the actual cause of the system failure, another approach was proposed. The system operation was studied throughout the cycle of operation and, it has been found that the failure of the wooden plank occurs because of the uneven stress being applied on the wooden planks because of different mode shapes of the steel and wood material during running condition of hopper. This happens since both the materials have different properties. The vibratory motion causes the wooden plank and steel plate to vibrate along with the system which thus generates the vibration in the plank which sets mode shapes in the plank. While wooden plank vibrates in first mode, steel plate was observed to be the second mode of vibration as shown in the figures 4.3.

Dynamic response analysis is study of actual behavior of wooden plank assembly during working condition. From fig 4.3 it can be seen that whenever hopper is running in sugar factory, load acting on hopper and dynamic forces creates mode shapes in wooden plank assembly.

Figure 4.3: Mode Shapes in Steel Plate

These different mode shapes in steel material develops uneven stress in the wooden plank. This makes the wooden plank fail at the end connection which is shown in the subsequent figures 4.3.1.

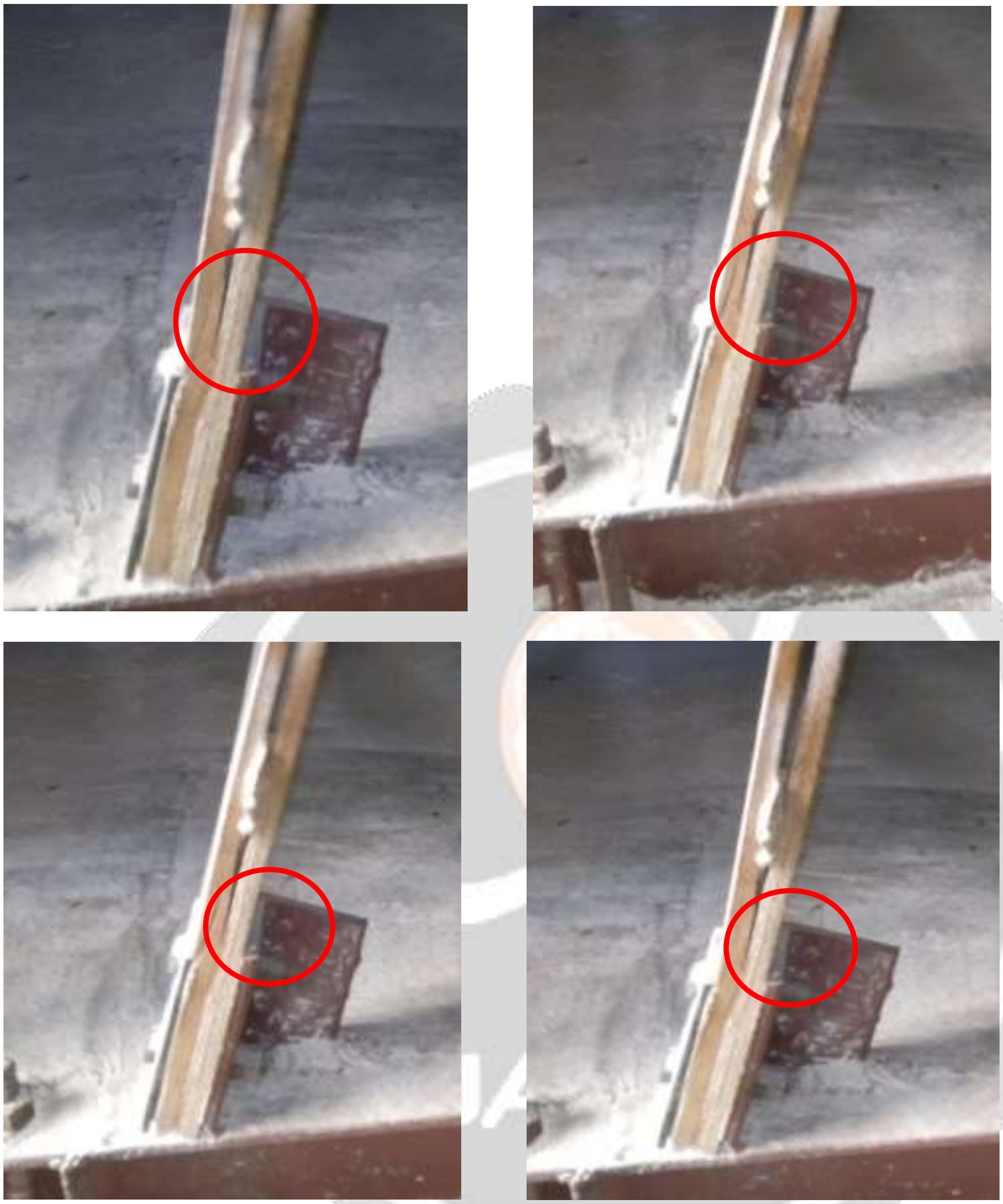

Figure 4.3.1: Failure of Wooden Plank

Practical analysis of the wooden plank system along with the therotical evidences leads to the conclusion that the reason of failure of wooden plank could be because of the knot present in the materia, fibre orientation or different material properties as well as because of the various operating conditions which do not favour the normal operation supporting the original properties. In present case, it is observed that the failure of the wooden plank because of different mode shapes in two different materials causing uneven stress creation which leads to the fracture in the wooden plank due to fatigue.

Among all the mentioned causes of failure most prominent type of failure is, the failure due to continuous fatigue observed mostly at the connection point. This failure further leads to the increase in the lead time and the tact time of the system. Another fact worth noting is that, whenever a wooden plank fails, operators replace the failed piece with another wooden plank which is observed to be of poor quality while it is supposed to be belonging to the family of pine wood. This also promotes the failure of plank as local wood does not possess all the necessary properties required for the application.

It is also observed that whenever a plank fails, the load distribution varies indefinitely among all other wooden planks; Thus causing localized stresses which further leads to the failure of other planks. This causes alignment problems, bearing failure due to uneven stresses.

5. FINITE ELEMENT ANALYSIS

The modelling of wooden flank is carried out in catiav5,R19,(Student Edition) and analysis on ANSYIS solver. Pretension in due to bolting is important because it will not only weaken the strength of shell but also generates boundary stress on the joint of wooden plank, leading to severe stress concentration. So the joint is most vulnerable part to failure. It's of great importance to study the influence of various parameters on stress distribution of the wooden plank. Due to different loadings applied to flange, a local stress state of the wooden plank connection characterized by high stress concentrations occurs in the lower portion of plank where it is fixed.

5.1 Structural Analysis of wooden plank

5.1.1 Pre-Processing

As far as pre-processing is concerned, it is the step in which required engineering data is provided to the solver i.e. ANSYS Workbench. In this analysis, the data given as input is, materials for wooden plank assembly are wood and mild steel.

5.1.2 Properties of Steel

Material Density for steel =7860 kg/m^3, Modulus of Elasticity=2.1x10^{5}Mpa, Poisson's Ratio=0.372, Ultimate Tensile Strength=320 MPa.

5.1.3 Properties of Pine Wood

Material Density for pine wood at 12% moisture = 515 kg/m^3, Modulus of Elasticity=1.1x10^{4}Mpa, Poisson's Ratio (μLR) = 0.347, Ultimate Tensile Strength=3200 KPa. Ultimate compressive Strength = 41900Kpa

5.1.4 Meshing

For meshing, Tetrahedron element is chosen as wooden plank has complex geometry in the form of curvature. Also, for better accuracy sizing is selected as proximity and curvature. Meshing is selected as fine mesh as shown in figure 5.1.4.

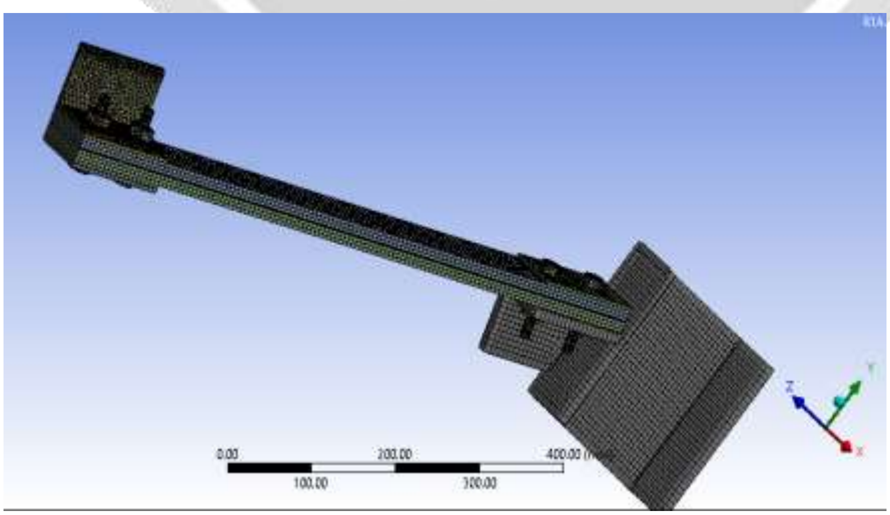

Figure 5.1.4: Meshing In Wooden Plank Assembly

5.1.5 Boundary Condition

All fasteners areas on wooden plank bolts (studs) are fixed (DOF restricted) and applied driving force per plank = 136.05 N. After applying these boundary conditions, the solver is allowed to solve the Current problem.

5.2 Structural Analysis Results

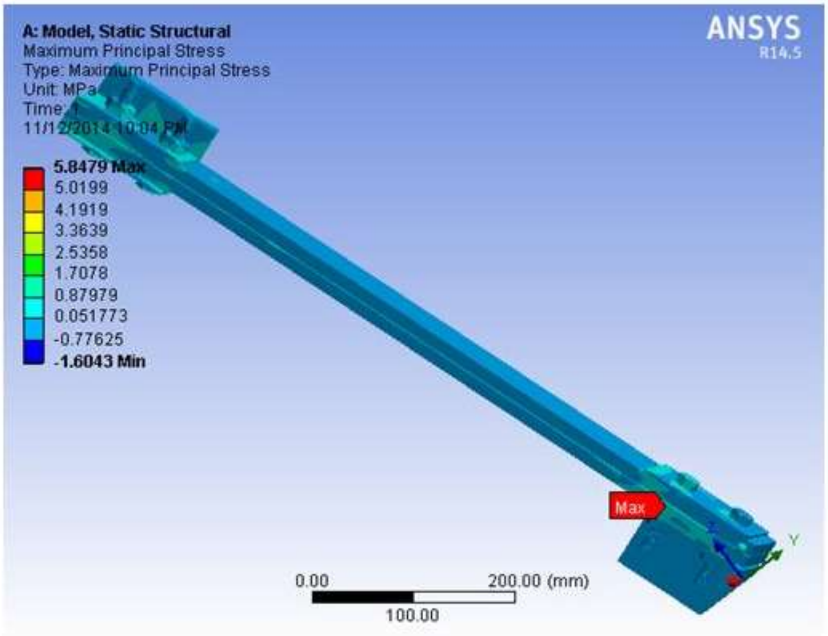

Figure 5-2-1: Maximum Principal Stress in Wooden Plank

Structural analysis shown in fig 5.2.1 shows maximum stress developed in the wooden plank assembly. The maximum stress value found is within the safe limit. It can be seen that the location of maximum stress developed in wooden plank at the end connection of plank. So there could more chances of failure occurred in that location.

Modal analysis:

Determines natural frequencies of a system (free vibration), including the effects of loading on a pre-stressed structure. Modal analysis on wooden plank is performed in workbench 14.5. Table 5.2 shows different frequency which is nothing but modal frequencies of wooden plank. Fig 5-2-2 shows total deformation of wooden plank at different frequencies.

Table5-2: Model analysis results

Mode	Frequency [Hz]
1.	97.084
2.	145.68
3.	502.91
4.	651.01
5.	984.12
6.	1525.8

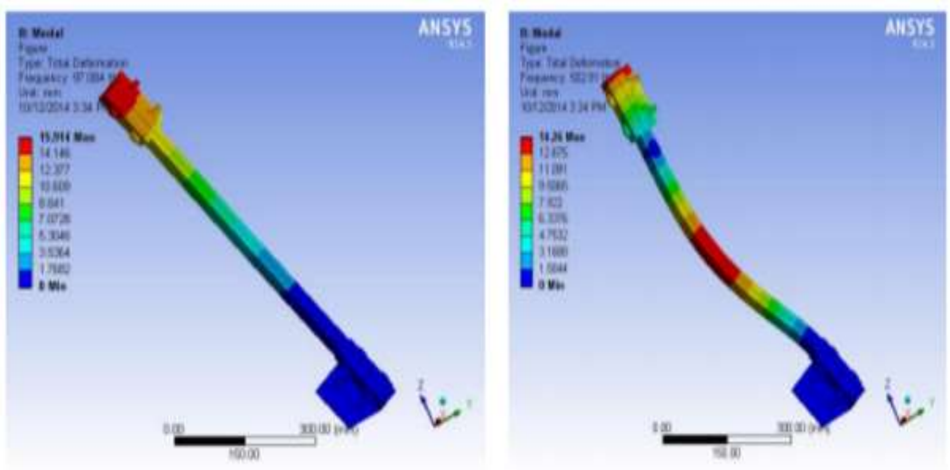

Figure 5-2-2: Total Deformation of Plank at Different Frequency

6. CONCLUSIONS

a. 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.
b. When wooden plank fails, crack present in wood structure start propagating, which produces uneven stresses in wooden plank. This degrades the performance of the system by causing bearing failure, other supporting planks failure, and alignment problems in the system & huge amount of vibration in the system.
c. From FEA analysis it is seen that the first natural frequency of wooden plank is far away from natural frequency of system, hence resonance won't occur in the system.

REFERENCES

[1] A.J. van Wyk, J.A. Snyman et al, "Optimization of a vibratory conveyor for reduced support reaction forces".
N&O JOERNAAL vol. 10, NR 1,1994, pp.12-17
[2] Ch.Viswarupachari, Anirvan Dasgupta, et al, "Vibration induced directed transport of particles", Journal of Vibration & Acoustics, Oct 2012, Vol. 134, pp. 1-6
[3] G.Winkler, "Analysing the vibrator conveyor" Int.j.Mech.Sci.Vol.20, 1978 pp. 561-570
[4] Rakesh Hota, Kshitij Kumar, et al "Experimental investigation of fiber glass reinforced mono-composite leaf spring", International Journal of Design & Manufacturing Technology, Volume 4, Issue 1, January – April (2013), pp. 30-42
[5] M.A.Parameswaran and S.Ganapathy, "Vibratory conveying-analysis and design: A review". Mechanism & Machine Theory, Volume 14, 1 May 1978 pp. 89-97
[6] G.L.Hinueber, "Reinforced plastic springs for vibratory conveyors".
[7] Rakesh A Oza, S P Patel. "Analysis and optimization of drive shaft in eccentric mechanical press" International Journal of engineering research and application (IJERA) Vol. 1, Issue 2, pp.055-058.
[8] R.Klages, I.F.Barna, L.Matyas, "Spiral modes in diffusion of a single granular particle on a vibrating surface. University of London, London EI 4NS, UK.Received 22 June 2004, accepted 30 September 2004.
[9] A.W.Roberts; P.C.Arnold, "Transverse vibration of auger conveyors." Wollongong University College, University of New south wales, Australia.
[10] Z.Bao, C.Eckelman, H.Gibson, "fatigue strength and allowable design stress of some wood composites used in furniture". Purdue University, West Lafayette, USA

[11] E.M.Sloot, N.P.Krupt, “Theoretical and experimental study of the transport of granular materials by inclined vibratory conveyors” university of Twente, Netherland.Received 22 March 1995; revised 25 October 1995.

[12] Dr.R.Rajappan, Dr.S.S.Sundararaj and V.Pugazhenthi. “Finite element modeling and analysis of skin panel based on the fiber orientation and stacking sequence” ISSN: 2278-1684 Volume 3, Issue 1(sep-oct 2012)

[13] David E. Krestchmann United State department of agriculture. “Wood Handbook. Wood as an engineering material” .general technical report FPL-GTR-190.

[14] Joseph E. Shigley, “Standard Handbook of Machine Design” second edition (1996).

[15] Singiresu S. Rao, “Mechanical Vibrations” 5^{th} edition.

[16] Robert Stone, “Fatigue Life Estimates Using Goodman Diagrams”.