Transfer Coal Conveyor Shaft Optimization Analysis and Modification in Sprocket Structure

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Abstract

This work present the optimization analysis of transfer coal conveyor shaft and modification in sprocket structure. An investigation will be performed to determine the failure root cause and factors affecting on transfer coal conveyor shaft. Finite Element Analysis (FEA) will also perform to quantify the stress distribution in the shaft. Thus the strength of shaft is to be important parameter to be taken into account while designing. The 3D model is prepared by using CATIA pre-processing and post-processing is prepared by using Ansys workbench. The load and boundary condition were applied in Ansys as per shaft mounting on conveyor. This process helps in finding the optimized design for the shaft in which it has the best performance without any failure.

Optimization of shaft was carried out by selecting better material for weight reduction and better strength. FEA also be carried out on optimized design of the shaft to check whether the optimized design is safe or not. FE Analysis has done using model and shaft deformation test carried out on Universal testing machine to validate analysis results.

Index Terms— Shaft, CATIA software, ANSYS software, Universal testing machine, Optimization.

I. INTRODUCTION

A conveyor system is a common piece of mechanical handling equipment that moves material from one location to another. It is used in transportation of heavy or bulky materials. Conveyor systems are very popular in material handling and packaging industries because it allows quick and efficient transportation for wide variety of materials. Many factors are important in the accurate selection of a conveyor system. Now day's major breakdown in continuous running plant is too costly. The gearbox and motor was directly coupled to the shaft with the help of chain and sprocket therefore overall subject of project is the optimization analysis of drive shaft which is used in transfer coal conveyor.

II. LITERATURE REVIEW

The different work to be carried out on transfer coal conveyor system in recent years. M.A. Alspaugh [1] works on "Latest Developments in Belt Conveyor Technology". This paper describes the application of conventional components in non-conventional applications for this requiring intermediate drives and horizontal curves have changed and expanded conveyor belt possibilities. S.H. Masood et. al. [2] works on "An investigation into design and manufacturing of mechanical conveyors systems for food processing". In this used the principles of design and concept of concurrent engineering for design of assembly and manufacturing. Investigation was done for several critical conveyor parts to check their strength criterion, functionality, material suitability, cost and ease of assembly in overall conveyor system. By using new materials the critical parts were modified and redesigned with new shape and geometry. Verification of the functionality of new conveyor parts and the improved design methods was done and were tested on a new test conveyor system designed, manufactured and assembled using the new

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improved parts. The new better technique is used for production and design of conveyor components for the reduction of materials, parts and costs. A. Goksenli et. al. [3] works on "Failure analysis of an elevator drive shaft". Paper describes failure occurred at the keyway of the shaft. After visual investigation of the fracture surface it is concluded that fracture occurred due to tensional bending fatigue. Fatigue crack has initiated at the keyway edge. Investigation was carried out to find reason of failure for this finite element method was used. It is concluded that fracture occurred because of manufacturing or design of keyway is incorrect. i.e. high notch effect occurs because of low radius of curvature at keyway corner. In conclusion by using FEM explain the effect of change in radius of curvature on stress distribution and in order to prevent similar failure which precautions have to be taken is clarified.

Gys van Zyl et. al. [4] this paper describes that during service the shaft of a conveyor belt drive pulley was failed. An investigation was performed in order to determine the failure root cause and contribution factors. Investigation methods included optical and scanning electron microscope analysis, visual examination, chemical analysis of the material and mechanical tests. In order to quantify the stress distribution in the shaft a finite element analysis was also performed. It is concluded that due to fatigue the shaft was failed and cause of shaft failure is due to inappropriate refit of the shaft during routine use.

Dima Nazzal et. Al. [5] works on "Survey of Research in Modeling Conveyor Based Automated Material Handling Systems in wafer fabs". This paper describes literature of models of conveyor systems in semiconductor fabs. A comprehensive overview of simulation-based models is provided. We also identify and discuss specific research problems and needs in the design and control of closed-loop conveyors. It is concluded that in order to understand the behavior of such systems and bridge the gap between theoretical research and industry problems a new analytical and simulation models of conveyor systems need to be developed. John Usher et. al. [6] this paper provides the details of analysis of the reliability and availability of two common designs of the line-shaft roller conveyor. The first is a standard design in which every roller is belted directly to a line shaft under the conveyor. In second design the only one top roller is belted to the line shaft and all other remaining rollers are belted to the one powered roller in a series arrangement. This design is done because of the upper belts are faster to replace than belts connected to the line shaft, so increasing system availability. However, the reliability of latter design is less in that the failure of a single belt may causes to multiple roller failures. C. Sekimoto [7] works on "Development of Concept Design CAD System". This paper discusses in order to shorten the product development time and improve the product quality, 3 dimensions at CAD/CAE system is essential. It is necessary to develop a system which utilizes the concept design data at the early stage for the whole process of the product development. The purpose of this paper is to improve the product quality by the sufficient design study iteration at the early stage of design. A CAD system which can be used for the conception design and a proper CAD environment should be developed and another purpose.

III. PROBLEM DEFINITION

A. Problem Statement:

In many industries the old conveyor system is used. But the weight of this old conveyor system is too much. So optimization is done to reduce material and cost.

B. Objective:

1) Investigate stress and deformation of Existing Conveyor shaft.
2) Optimization of shaft is done by selecting better material for weight reduction and better strength.
3) Experimental testing is done to validate analysis results of optimize shaft.

IV. FAILURE CAUSES OF SHAFT

There are only four basic failure mechanisms:

1) Corrosion
2) Wear
3) Overload
4) Fatigue

The corrosion and wear never cause machine shaft failures but fatigues is more common than overload failure. No shaft materials are absolutely brittle or absolutely ductile but it is relatively ductile. As a result when an extreme overload is placed on these materials, they twist and distort. Shaft failure occurs in overloading because of torsional stress. Because of cyclical stresses fatigue is occur and the forces that cause fatigue failures are less than those that would cause plastic deformation.

V. DESIGN CHECK OF EXISTING SHAFT

A. Existing Material Properties:

TABLE.1
Mild Steel Properties

Properties of Material	Value
Young's Modulus E	210 GPa
Density ρ	7860 Kg/m^3
Yield Strength S_{yt}	560 MPa

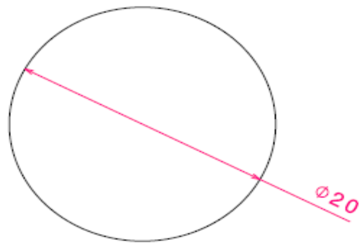

Fig.1. Existing Shaft Diameter

Allowable Stress (σ_{all}) = S_{yt}/F_s = 560/2=280 MPa

B. Calculation by considering given shaft dimension:

W= 200/4= 50 kg (Load act on 4 rollers at a time)

D = Outer diameter of shaft = 20 mm

w = Width of shaft = 660 mm

y = Distance from neutral axis = 0.02/2 = 0.01

C. Maximum Moment (M_{max}):

$M_{max} = W*L^2/8$

$= (50*9.81*0.66^2)/8$

Maximum Moment M_{max}= 26.7077 N-m

D. Moment of Inertia (I):

$I = \Pi (D^4)/64$

$=\Pi (0.02^4)/64$

Moment of Inertia I = $7.8540*10^{-9}$ m^4

E. Maximum Bending Stress (σ_b):

$\sigma_b = M_{max} * y / I$

$= 26.7077 * 0.01/7.8540*10^{-9}$

Maximum Bending Stress σ_b =34.005MPa

F. Checking Factor of Safety for design:

$F_s = \sigma_{all} / \sigma_b$

= 280/34.005

Factor of Safety F_s= 8.234

As Calculated F_s is greater than assumed F_s, Selected Material can be considered as safe. Actually it's over safe condition because available FOS is too high

VI. ANALYSIS OF EXISTING SHAFT

A static analysis forecast the effect of steady loading condition on structure, while forgetting damping and inertia effects, such as those caused by time varying loads. A static analysis include steady inertia load such as gravity and rotational. Static analysis resolves the displacements, stresses, strains, and forces in structures or components caused by loads. That does not induce significant inertia and damping effects. For analysis of existing shaft firstly drawing with evaluated dimensions is made in CATIA. After this model imported in ANSYS. Forces and boundary condition applied to the model then meshing of shaft using hexahedral element is done and the result of the analysis shows stresses and deformation of existing shaft material. The result obtained in analysis shown below:

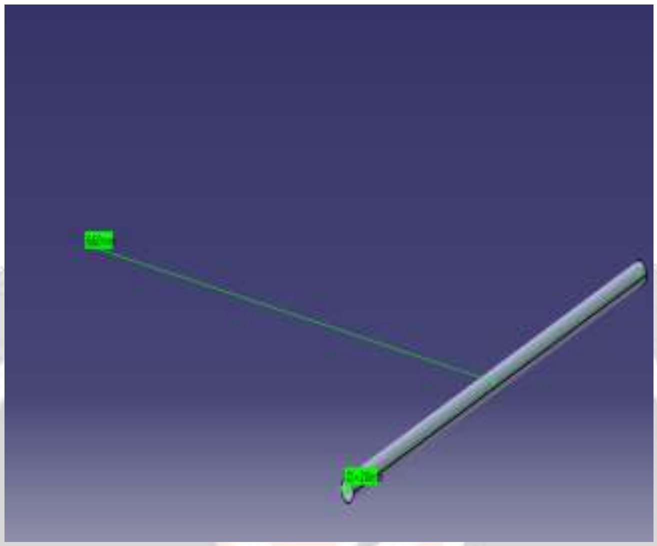

Fig.2. CATIA model of shaft

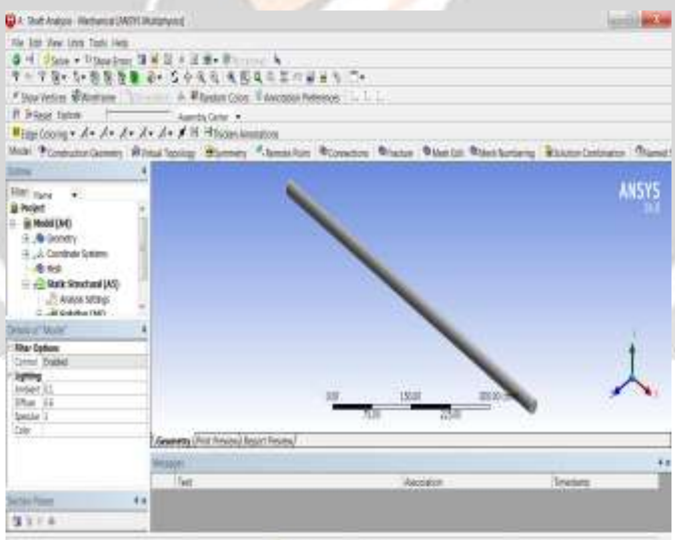

Fig.3. Shaft model imported in ANSYS

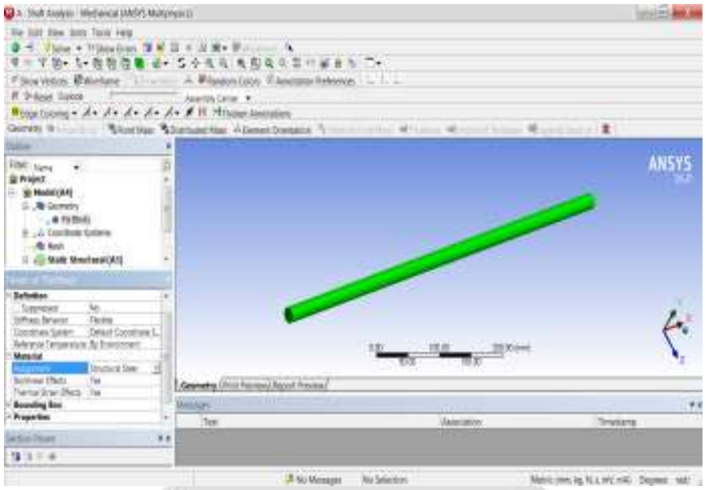

Fig.4. Shaft model material assignments

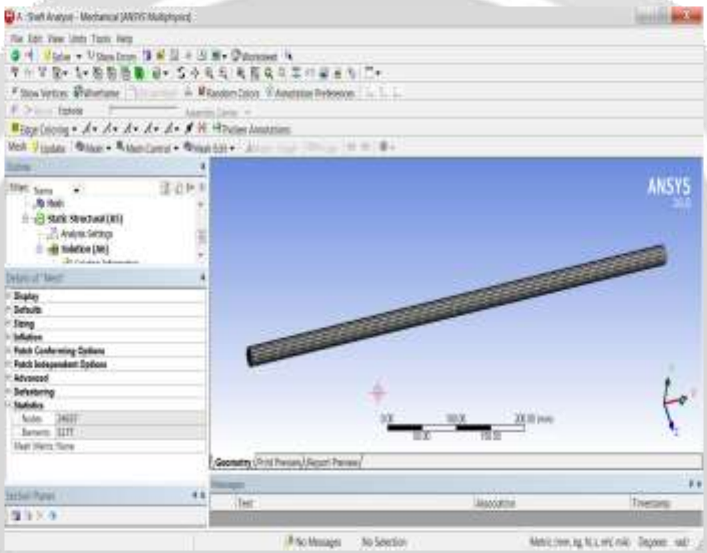

Fig.5. Meshing of the shaft using hexahedral elements

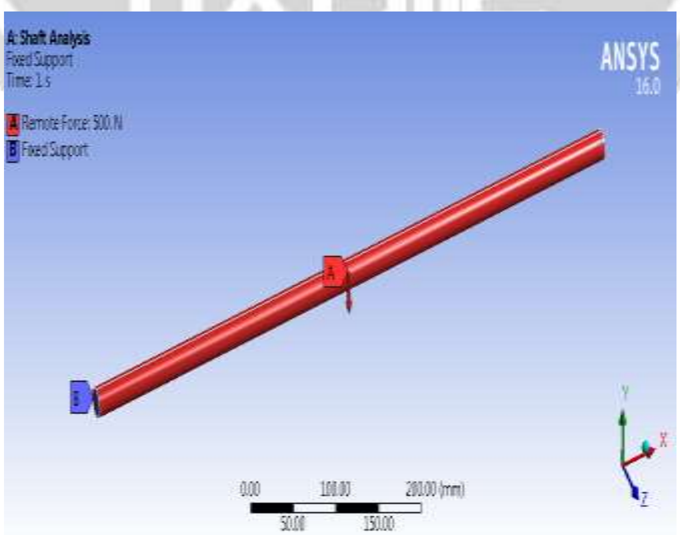

Fig.6. Boundary condition on shaft

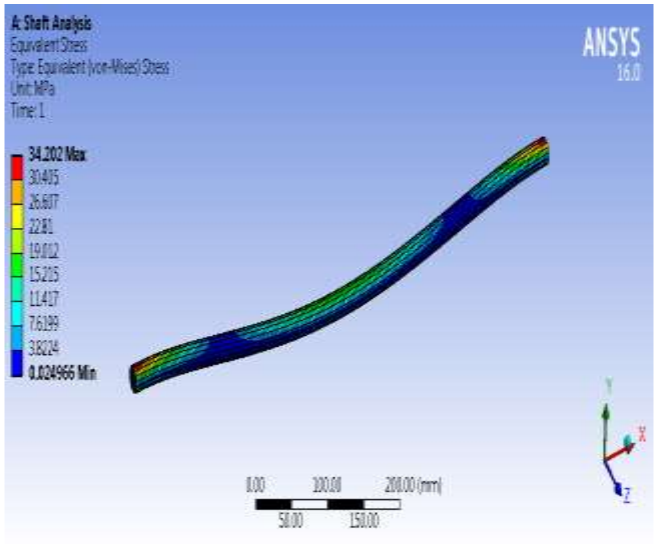

Fig.7. Von Misses Stresses in the shaft

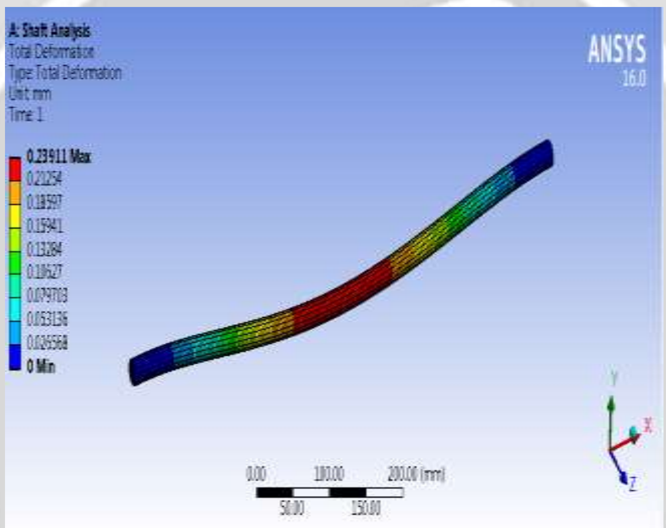

Fig.8. Deformation in shaft

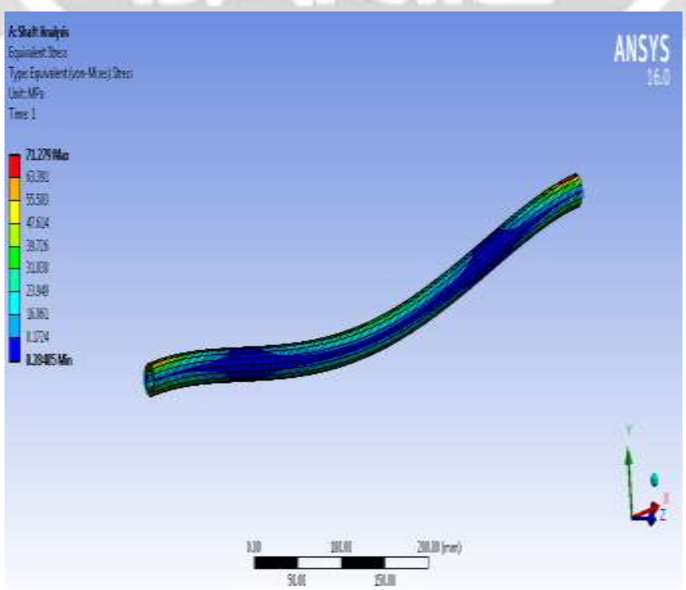

Fig.9. Von Misses Stresses in hollow shaft

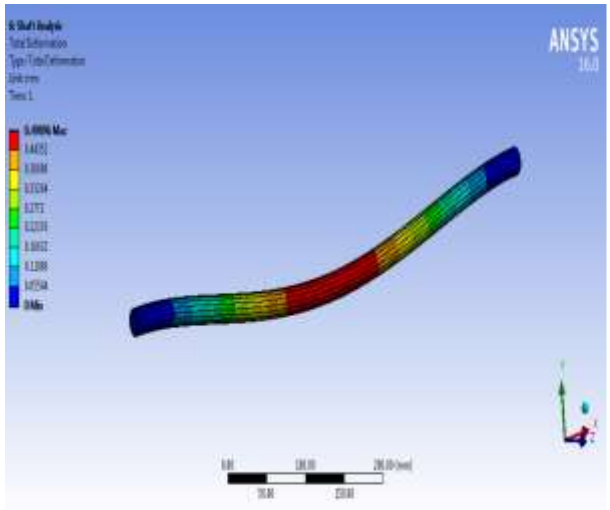

Fig.10. Deformation in hollow shaft

For solid shaft maximum deformation 0.23911 mm and von mises stress is 34.202 MPa and for hollow shaft maximum deformation 0.49896 mm and von mises stress is 71.279 MPa.

VII. COMPOSIT MATERIAL ANALYSIS

A composite material is made by combining two or more materials, ones that have very different properties. The two materials work together to give the composite unique properties. Benefits of composite material:

- Light weight
- Non corrosive
- Non conductive
- Flexible
- Low maintenance
- Long life
- Design flexibility

Modulus of elasticity (E), Modulus of rigidity (G), Poisson Ratio (υ) these poperties are considered for FEA of composite material. These properties used from engineering data manager.

A. Analysis based on different orientations angles:

- 90/0/90/0 orientation angle:

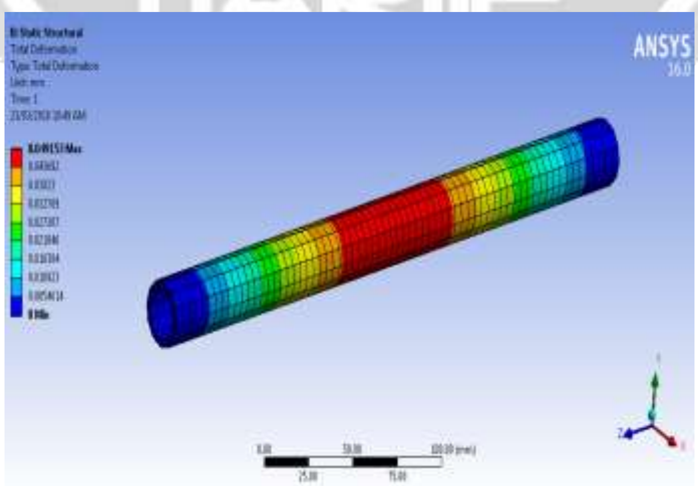

Fig.11. Deformation on shaft

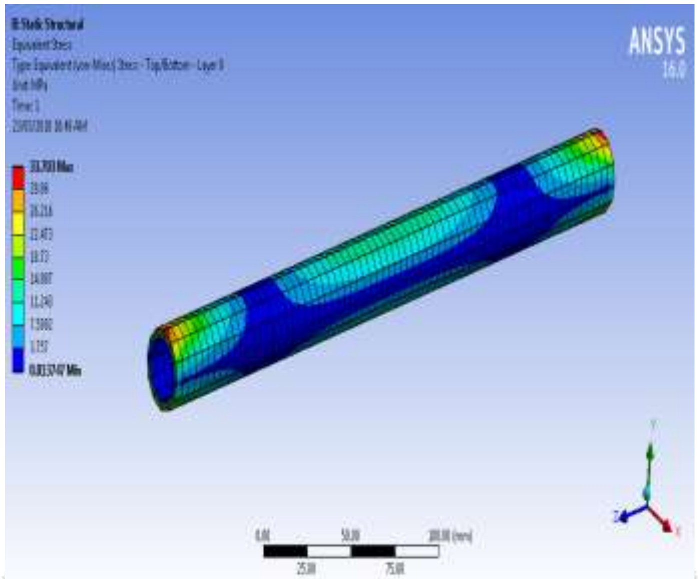

Fig.12. Stresses on shaft

TABLE.2
Analysis results for different orientations angles

Orientations	Stress (MPa)	Deformation (mm)
90/90/90/90	44.937	0.065537
45/0/45/0	62.912	0.091752
90/0/90/0	33.703	0.049153
30/0/30/0	62.013	0.090442
60/0/60/0	56.171	0.081922
30/60/30/60	71.9	0.10486
45/90/45/90	49.431	0.072091
90/90/90/90	44.937	0.065537
45/0/45/0	62.912	0.091752

From above results it can be seen that the stresses in steel shaft is higher than composite shaft by considerable values. Also we can see that deformation is on higher side in composite layers.
Layer orienttion 90/0/90/0 gives better result hence considered for final case.

B. Analysis based on different composite material:

Materials selected for further analysis:

- Carbon Epoxy Woven
- E-Glass Epoxy
- Resin Epoxy

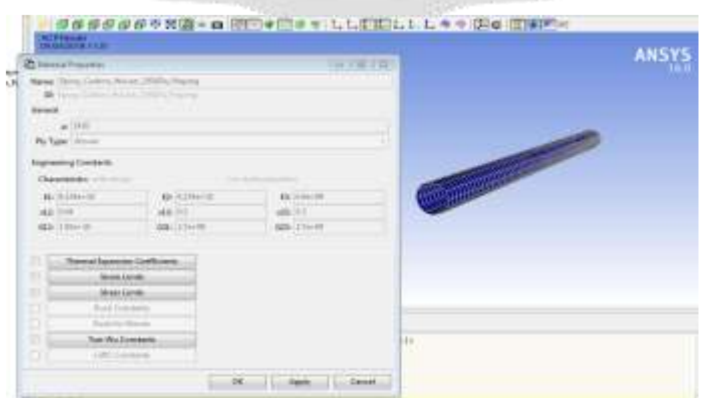

Fig.13. Application of Carbon Epoxy Woven material

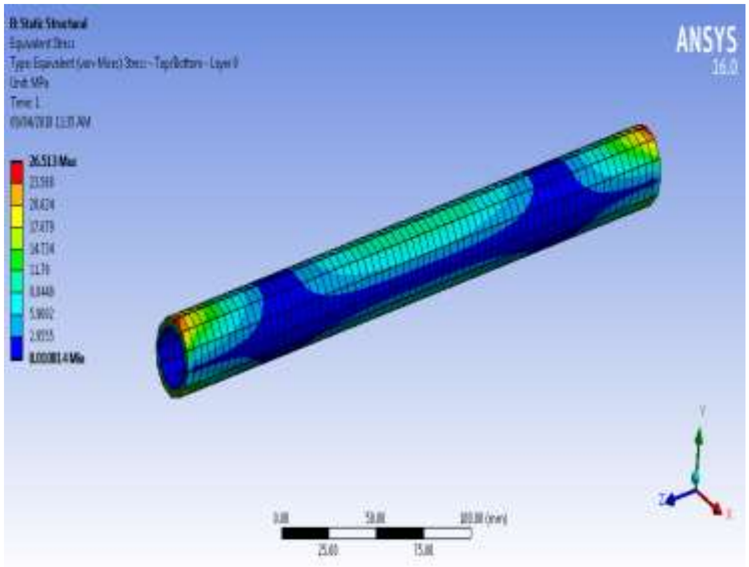

Fig.14. stresses using Carbon Epoxy Woven Material

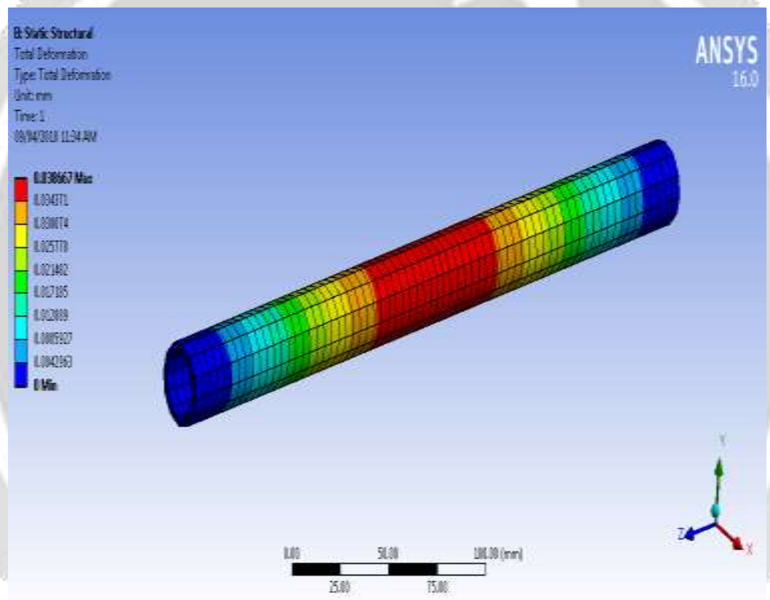

Fig.15. Deformation using Carbon Epoxy Woven Material

TABLE.3
Analysis results for different materials

Sr. No.	**Orientations**	**Material**	**Stress (MPa)**	**Deformation (mm)**
1	90/0/90/0	Carbon Epoxy UD	33.703	0.049153
2	90/0/90/0	Carbon Epoxy Woven	26.513	0.038667
3	90/0/90/0	E-Glass Epoxy	58.418	0.085199
4	90/0/90/0	Resin Epoxy	51.678	0.075368

Carbon Epoxy with Woven (90/0/90/0) gives better results among selected materials.

VIII. EXPERIMENTAL TESTING

A universal testing machine (UTM), also known as a universal tester, is used to test the tensile strength and compressive strength of materials. Experimentation is done for analyzing the shaft's deformation. As FOS is high for shaft so stresses are of secondary importance.

A. Machine Specifications UTM:

TABLE.4
UTM Specifications

Max Load Capacity	100KN
Load Accuracy	Within +/-1%
Test Space Tensile Compression	 680 mm 620 mm
Piston Stroke	250 mm
Dimensions	700*610*2200 mm
Power Supply	Three-Phase, 240V-50HZ

Fig.16. Testing of Shaft on UTM

B. Experimental Test Results for Carbon Epoxy Woven:

Testing of conveyor shaft having Carbon Epoxy Woven material shown in table below:

TABLE.5
Test Result on UTM

Material	**Deformation, mm (Experimental)**			
Carbon Epoxy Woven At (90/0/90/0) orientation	Trial 1	Trial 2	Trial 3	Avg.
	0.041	0.039	0.041	0.040

IX. CONCLUSION

- Orientation optimization study is done and final Orientations selected are 90/0/90/0.
- Material optimization is done and carbon epoxy woven material is suggested so strength of shaft is improved and weight is reduced.
- Stresses and deformation are less for optimized selection than existing shaft.
- FEA and Experimental deformation results for optimized shaft shows only 4.17% error.

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