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Design Analysis of Pulley Using Mild Steel and Carbon Epoxy Material

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Abstract- **Conveyors are essential to productivity, from light-duty package-handling roller conveyors in distribution centers to overhead and towline chain conveyors carrying automobiles through assembly to massive ore-handling belt conveyors. To avert production stoppages due to conveyor failure, progressive companies use predictive condition monitoring technologies to monitor those assets. The objective is to detect impending failures before they occur, and take corrective action during scheduled production shutdowns. One of those technologies is thermograph, or IR Imaging. Thermal imagers capture two dimensional images representing the apparent surface temperatures of conveyor components, and are excellent tools for monitoring conveyors.**

Overland Conveyor Design

- Static and dynamic analysis
- Complete design specifications
- Control theory
- Feasibility studies and cost estimation
- Terrain modeling with earthwork optimizations
- Rubber visco elasticity for accurate power predictions
- Commercial software for conveyor design

I. INTRODUCTION

A conveyor belt (or belt conveyor) consists of two or more pulleys, with a continuous loop of material - the conveyor belt - that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler. There are two main industrial classes of belt conveyors; those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport industrial and agricultural materials, such as grain, coal, ores, etc. generally in outdoor locations. Generally companies providing general material handling type belt conveyors do not provide the conveyors for bulk material handling. In addition there are a number of commercial applications of belt conveyors such as those in grocery stores.

The belt consists of one or more layers of material they can be made out of rubber. Many belts in general material handling have two layers. An under layer of material to provide linear strength and shape called a carcass and an over layer called the cover. The carcass is often a cotton or plastic web or mesh. The cover is often various rubber or plastic compounds specified by use of the belt. Covers can be made from more exotic materials for unusual applications such as silicone for heat or gum rubber when traction is essential.

Material flowing over the belt may be weighed in transit using a belt weigher. Belts with regularly spaced partitions, known as *elevator belts*, are used for transporting loose materials up steep inclines. Belt Conveyors are used in self-unloading bulk freighters and in live bottom trucks. Conveyor technology is also used in conveyor transport such as moving sidewalks or escalators, as well as on many manufacturing assembly lines. Stores often have conveyor belts at the check-out counter to move shopping items. Ski areas also use conveyor belts to transport skiers up the hill.

A wide variety of related conveying machines are available, different as regards principle of operation, means and direction of conveyance, including screw conveyors, vibrating conveyors, pneumatic conveyors, the moving floor system, which uses reciprocating slats to move cargo, and roller conveyor system, which uses a series of powered rollers to convey boxes or pallets.

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1.1. The Structure and Loading of the Conveyor Belts

There are often used conveyors with the belt with textile carcass to transport the material in mining industry. The carcass provides the necessary strength and impact resistance for the conveyor belt, and it is also used to force transmission. It could be defined as a multi-element part of the conveyor belt connected with elastic material, which ensures the connection of the single components with one another and the dispersal of the energy at conveyor belt in operation. The top cover and protective edge enwind the carcass and protect it against the mechanical damage caused by transported material, against humidity impact and also against chemical and thermal influence affecting the conveyor belt. The bottom cover interacts with the rollers and with the drums of the conveyor and defends the carcass against their negative impact.

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The wearing of the conveyor belts depends on different factors, but mainly on operating conditions of the belt and on the type of transported material. The conveyors are continuous transport systems, which are able to transfer significant quantum of material. The downtime required for the repair or exchange of the broken belt always means huge economic costs. The wearing could have many causes. The belt is under wearing mostly at the input place where the conveyer is loaded. According to the experience from the operation of a belt, it is stated that up to 80% of all damages of a conveyor belt are at the loading place of conveyor at the input place.

The impact force, which is one of the basic reasons of conveyor belt wearing, rises at the input places. This point load is the consequence of the impact of the sharp-edged pieces of the transported material on the belt. If the impact energy is greater than the capability of the consoles, and of the conveyor belt to absorb this energy, then the conveyor belt damage occurs; first of all, the top cover in the form of transverse and longitudinal scratches, punctures and perforations. The impact resistance is related with the wearing, eventually with the damage of conveyor belts on the input places. This property is one of the most important properties, but it is not classified yet.

1.2 Mathematical Modelling of Conveyor Belts

The problem of testing the resistance of conveyor belts against perforation is very difficult because the belt consists not only of textile carcass, but also of materials with hyper elastic properties (rubber). The general scheme of problem solving in the program ANSYS is visible in the General scheme of problem solving in the ANSYS program Mathematical modeling means the usage of the mathematical formulas and relations in order to simulate the real situation. For example it is the simulation of the conveyor belt strains. Various parameters, for example size of density and deformation in the point of force application etc. can be the results of modeling. The all calculation is made by computer program that is based on finite element method. Much lower costs are one of the advantages of mathematical modeling, especially in comparison with other methods (for example the experimental research).

The next big advantage is based on the possibility of input data changes and on the very fast solutions of various versions of the given problem. . Mathematical model of conveyor belt we can see, in the previous scheme, that the first step of solution is *the model building*, or its import from specialized software. In this step, we create geometrical shape of final model called solid model. The next step is *the choice of element and the definition of material properties* (physical, technological and mechanical properties). The element type determines, for instance, whether the final model is plane (2-D) or space (3-D).

The element *HYPER58* was selected *to model the cover layers* of a conveyor belt. It is 8-node element given for the *3-D* modeling of a solid hyper elastic structure. It is used for material modeling which is nearly uncompressible (for example rubber and similar materials with great displacements and deformations). *Meshing the model. It is a* process in which the MKP model is built from the *solid* model. We need to choose suitable size and number of particular elements because the solution must be as exact as 3D mathematical model of conveyor belt... 183 possible, but at the same time the calculation must not be much longer in consequence of a large number of the elements. Material properties of particular elements are given in the Input data for mathematical model Rubber cover layers Textile carcass

Hyper elastic material constants

A = -0.52 MPa

B = 1.477 MPa

Poisson's number

μ = *0.499*

Rubber density

ρ*G = 1150 kg.m-3*

Modulus of elasticity for belt P 1000/4

E = 5500 MPa (according to the STN 26 0378)

Modulus of elasticity for belt P 2000/4

E = 9000 MPa (according to the STN 26 0378)

Poisson's number

μ = *0.3*

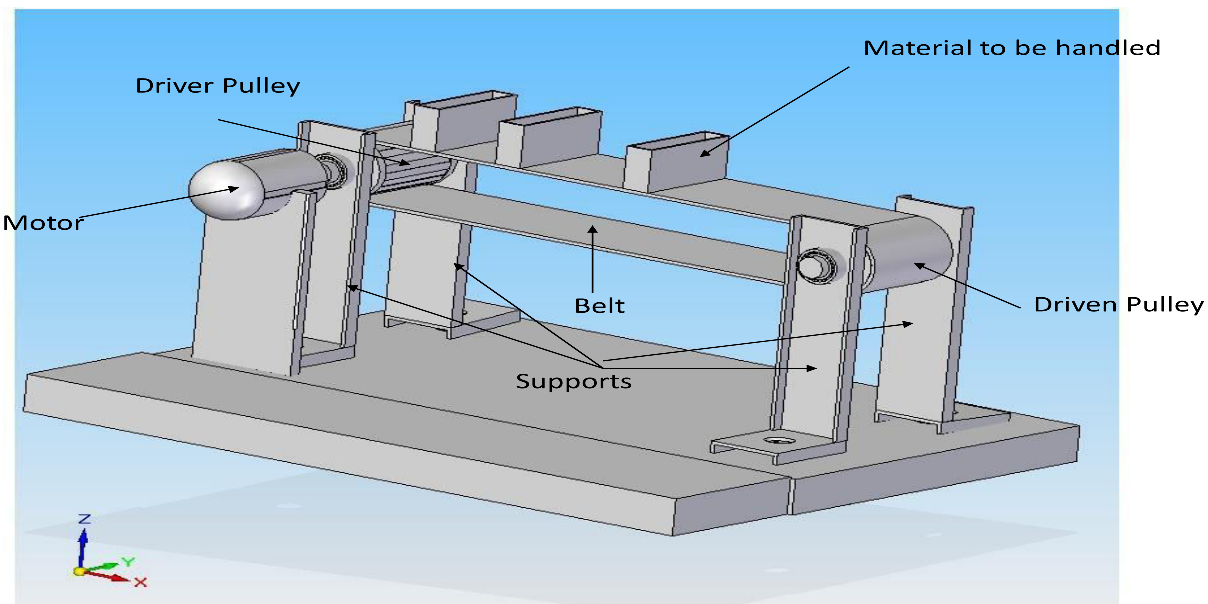
Textile carcass density

ρ*K = 1100 kg.m-3*

The setting of analyses, the application of loads, the determination of boundary conditions and the making of the solution is the fourth step that is executed in the part of program called Solution. Before the load application, it is necessary to set analysis parameters i.e., an analysis type, solution methods (Newton-Raphson) and some other parameters that are necessary for the solution of the given problem.

The solving starts by using the command *[SOLVE]* after assigning the boundary marginal conditions. The review of the results and its evaluation is the last step. We can browse the solution results by using the module post-processing. This module consists of two sub modules POST1 and POST26. POST1 serves to review the solution results in the whole model in the particular instant of time. POST26 project results only in the particular point of the model in dependence on time. It is possible to represent the results in textual or graphical form. The graphics offers a great clearness in the analysis of results.

On the Figure 1.1 is seen the model of a conveyor belt with applied boundary conditions and it is ready to initialize the calculation.



Conveyor System

1.3 Aim and Scope

The problem identification in existing design is

- Replacement of pulley in flow line due to low life cycle.
- High energy consumption due to conveyor system & material handling mass.

- High cycle times due to pulley struck.

The main aim of this project is to

- Reduce mass
- Low cost
- Low power consumption
- Low life cycle time.
- Low deformation rate & maintenance.
- High mechanical efficiency.

II. DESIGN METHODOLOGY

The pulley assemblies are initially designed component-wise, based on established practice and Standards, as available. All design parameters such as belt tension, motor power (for drive pulley), and angle of wrap, speed, belt width and overall dimensions (diameter, face width, web and bearing centers) are duly considered. The taper locks and bearings are sized based on the manufacturers' technical catalog and advice.

After basic design, all the three types of major pulleys (viz., D1/D2, ND1/ND2 & ND3/ND4) have been analyzed using Finite Element Method considering the overall pulley as an integrated structure. Solid Works and ANSYS software have been used for the modeling and analysis respectively. The Von Mises stresses in the shell and web have been studied.

Factor of safety for all the parts have been estimated. The parts are adequately sized ensuring that the stresses and deflections are within safe limits, providing a long life against fatigue. Only the end results of all iterative trials and calculations are reported.

Thus, the design process broadly consists of three parts as reported below. The formulas and considerations are discussed in the respective Chapters of this Report.

1. Basic Design Calculation
2. Finite Element Analysis
3. Fatigue Consideration

Basic Design Calculation

The resultant belt tension, bending moment and torque (for drive pulleys) are evaluated here to individually work out the shaft diameter, thickness of rim and web. Also taper lock and bearing sizes are obtained. Necessary calculations have been furnished.

Formula Used For Calculation

Combined Torsion Moment $Te = T^2 + M^2$

Combined Bending Moment $Me = \frac{1}{2} (M + Te)$

Where,

$T \rightarrow$ Driving Torque

$M \rightarrow$ Shaft Bending Moment

Finite Element Analysis

Based on the sizes and profiles obtained earlier, the stresses and displacements in different parts of the rim and web are obtained here. Since the shaft diameters, taper lock and bearing sizes are calculated from established procedures the stresses in these parts are not reviewed in detail here. The basic 3-D model is developed by Solid Works and analysis is carried out using ANSYS software.

Finite Element Model

For the analysis, the pulley has been modeled as an integral structure, freely supported at the bearings. Brick Element meshing has been used for the analysis. All degrees of freedom of the nodes in the core of shaft at the fixed bearing area have been arrested. At the other bearing end (floating), the radial displacements of the core nodes is arrested. Axial, radial and torsional displacements of the outer nodes at the bearings have been left unconstrained to allow for shaft flexure due to self-aligning bearings. The torsional displacement of the nodes at the drive end face (for drive pulley) is arrested to balance the torque caused by belt friction on rim. All six degrees of freedom at other nodes are allowed to reflect free bending and elongation/compression of all parts.

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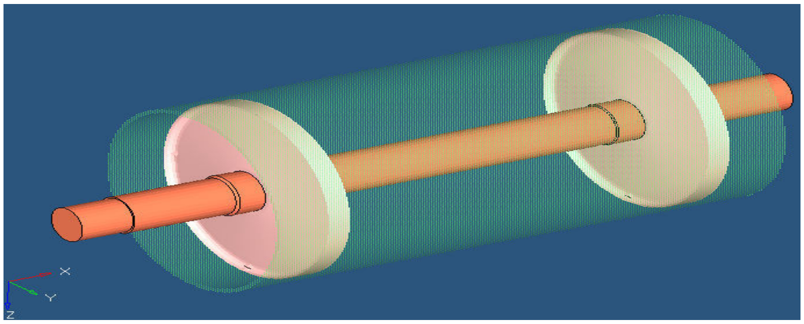
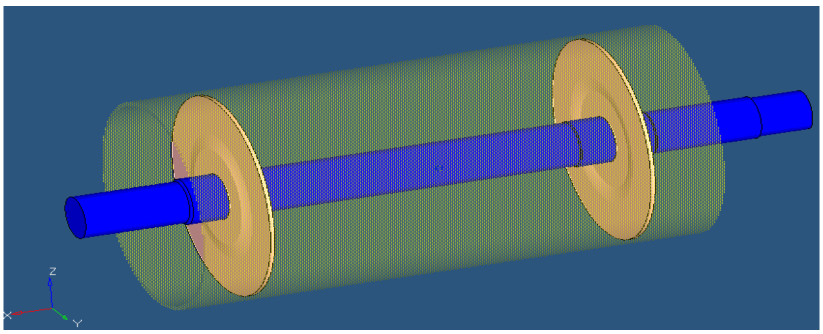
Pulley FE Model

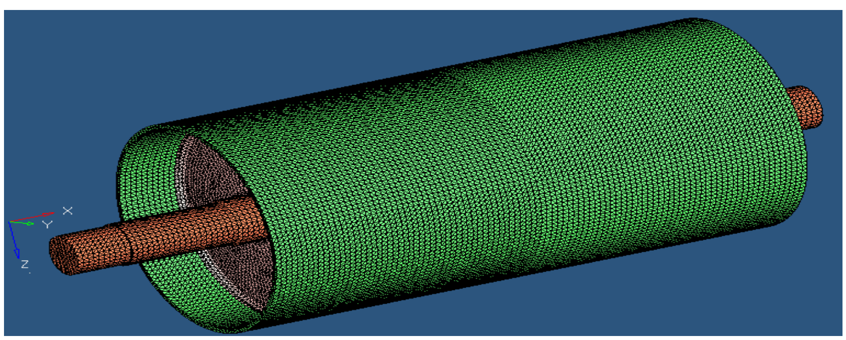


Mild Steel



Carbon Epoxy

Pulley FE Discretization



Mild Steel

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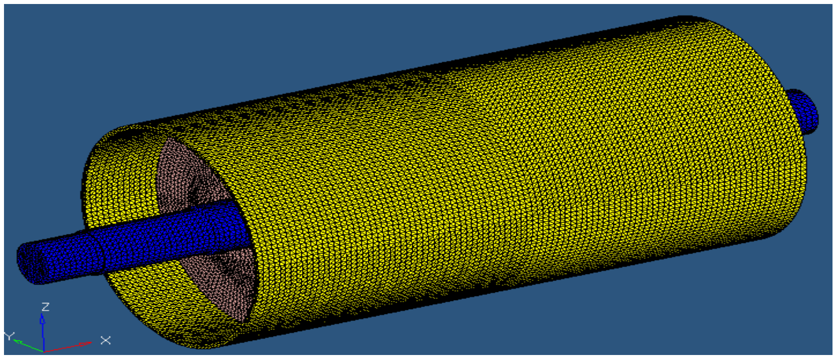


Carbon Epoxy

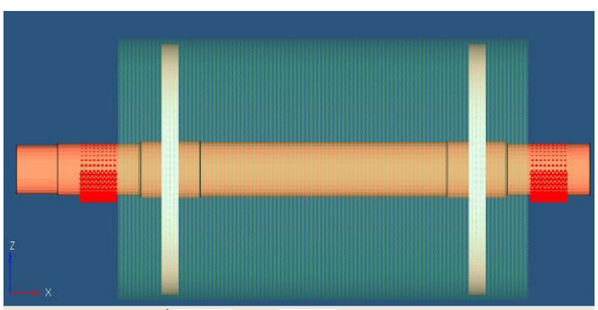
FE Nodes & Elements

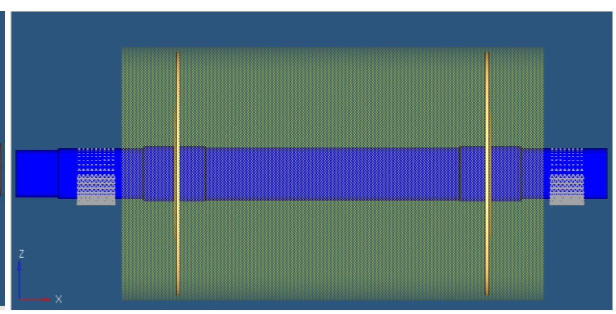
The FE nodes &Elements are listed in the following table:

Description	Mild Steel	Carbon Epoxy
No. of Nodes	48016	47324
No. of Elements	159304	152956

III. LOAD & BOUNDARY CONDITION

Fixed at bearing location





Fatigue Consideration

The stresses in different parts of pulley undergo cyclic changes since it is a rotating structure. The maximum and minimum Von Mises stresses in rim and webs are obtained from finite element analysis in various corresponding zones. These stresses have been used to evaluate the effective factor of safety from the well-known Sörderberg equation. Approximate S-N diagram has been obtained to estimate the fatigue life.

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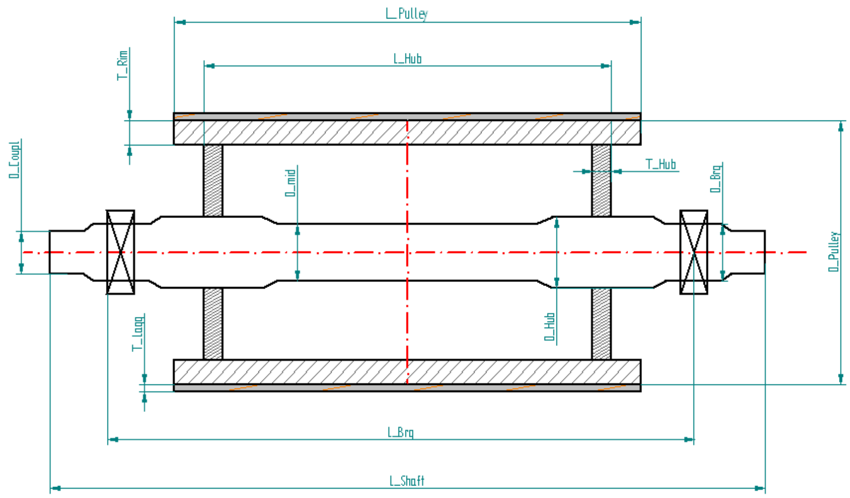
The drive shaft, in particular is subjected to combined reverse bending stress with constant torsional stress. The endurance limit for shafts is further checked considering various modifying factors as recommended in ANSI-105B. The fatigue life in all cases is found be beyond 20 years.

Pulley Nomenclature



Mild Steel Properties

Structural	
Young's Modulus	2.1e+011 Pa
Poisson's Ratio	0.303
Density	7860kg/m^3
Thermal Expansion	1300 /˚C
Thermal	
Thermal Conductivity	40 W/m˚C
Specific Heat	511.2 J/kg˚C

Carbon Epoxy Properties

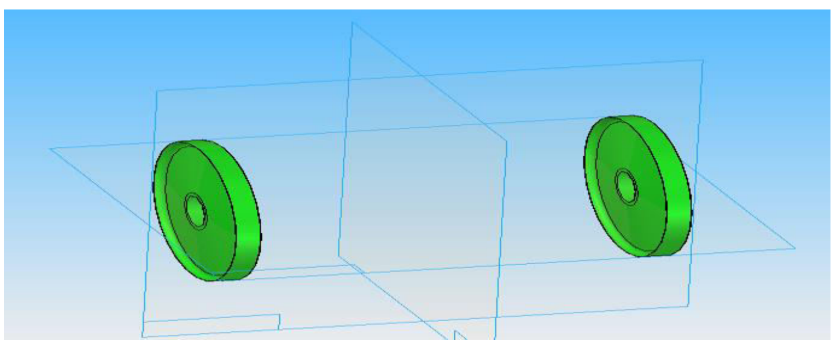
Structural	
Young's Modulus	1.2e+011 Pa
Poisson's Ratio	0.32
Density	1600

	kg/m^3
Thermal Expansion	28 ˚C
Tensile Strength Pa	5 e+007
Thermal	
Thermal Conductivity	15 W/m˚C
Specific Heat	1530 J/kg˚C

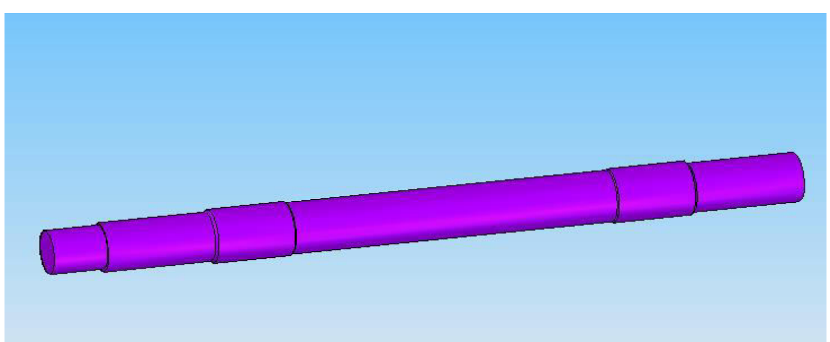
IV. MODELLING (SOLID WORKS MODEL)

Solid Works is a 3D CAD parametric feature solid modeling software. It runs on Microsoft Windows and provides solid modeling, assembly modeling and drafting functionality for mechanical engineers. Through third party applications it has links to many other Product Lifecycle Management (PLM) technologies. The Major Commands used are line, circle, and rectangle, revolve, extrude, create hexagon, and sweep features.

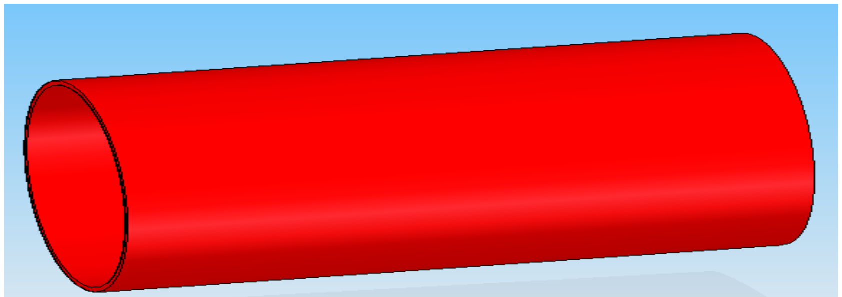
Pulley Components - Mild Steel (Existing Design)



Web Plate

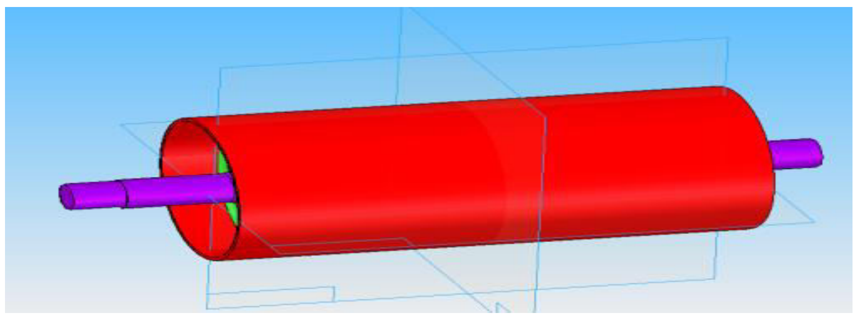


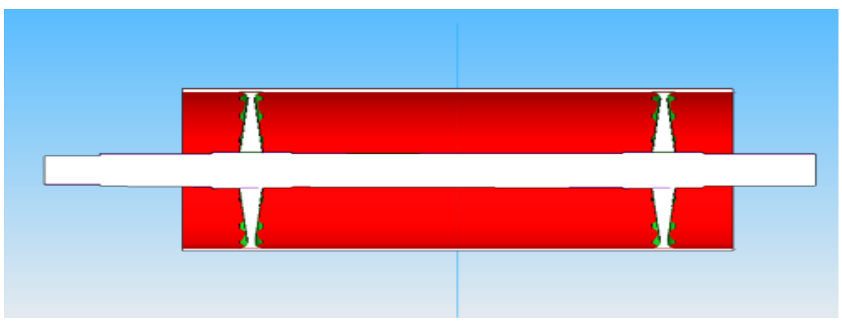
Shaft



RIM

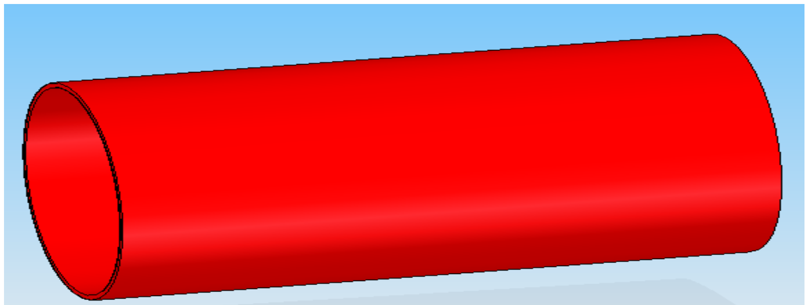
Pulley Assembly - Mild Steel





Front Section View

Pulley Components - Carbon Epoxy (Modified Design)



RIM

Pulley Assembly in Modified Design (Carbon Epoxy)

Web/hub as a sheet metal part

IV. ANSYS REPORT

Introduction about ANSYS

ANSYS is the software used for commonly analysis the structural and thermal calculations. So we have taken this as calculation package for the following advantages.

1. It is powerful package for structural and thermal analysis.
2. Reduce the manual errors during hand calculations.
3. Repetitive analysis is possible.
4. The part is divided into small elements called quadratic, tetra-hetra elements which produce most accurate results.

ANSYS is an engineering simulation software provider founded by software engineer John Swanson. It develops general-purpose finite element analysis and computational fluid dynamics software. While ANSYS has developed a range of computer-aided engineering (CAE)

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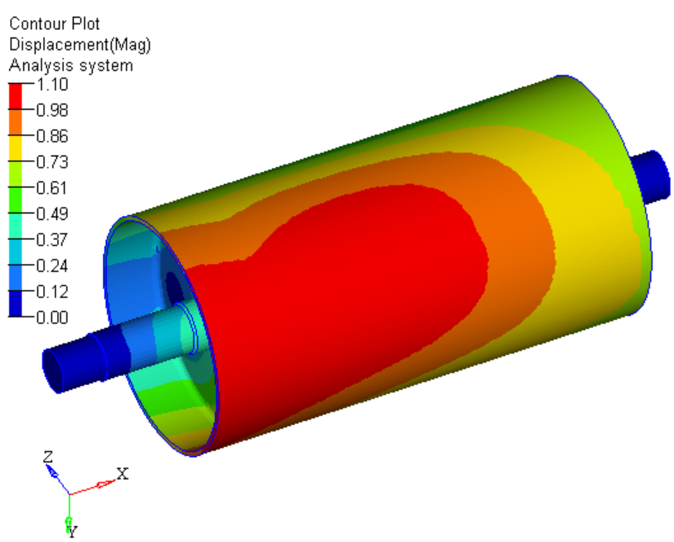
products, it is perhaps best known for its ANSYS Mechanical and ANSYS Multi physics products.

ANSYS Mechanical and ANSYS Multi physics software are non exportable analysis tools incorporating pre-processing (geometry creation, meshing), solver and post-processing modules in a graphical user interface. These are general-purpose finite element modeling packages for numerically solving mechanical problems, including static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

ANSYS Mechanical technology incorporates both structural and material non-linearities. ANSYS Multiphysics software includes solvers for thermal, structural, CFD, electromagnetics, and acoustics and can sometimes couple these separate physics together in order to address multidisciplinary applications. ANSYS software can also be used in civil engineering, electrical engineering, physics and chemistry.

Material Properties of Mild Steel Material

Ansys Import Model



Deformation in Mild Steel

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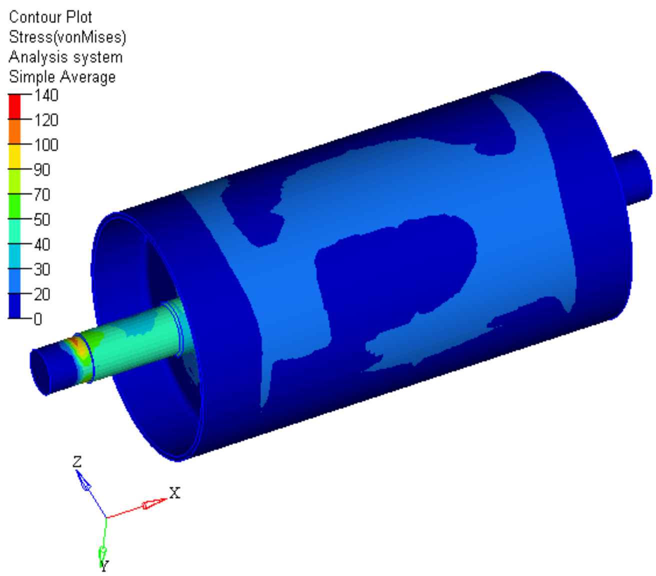
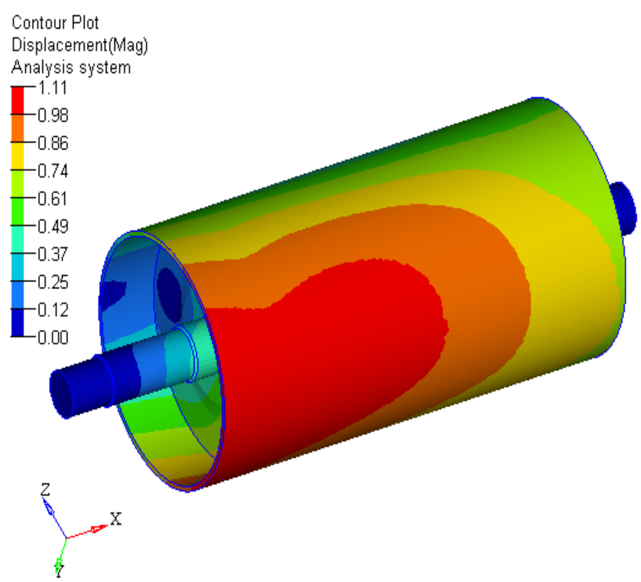


Von Mises stresses in assembly (Mild Steel)

Material Properties of Epoxy Carbon Material

Ansys Import Model



Deformation in Epoxy Carbon Material

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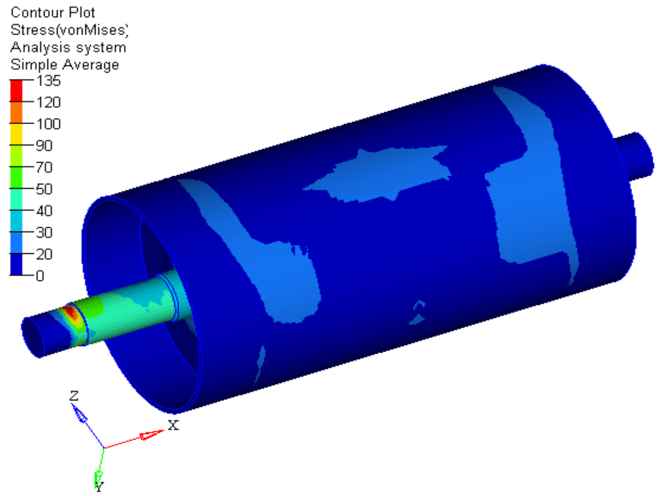
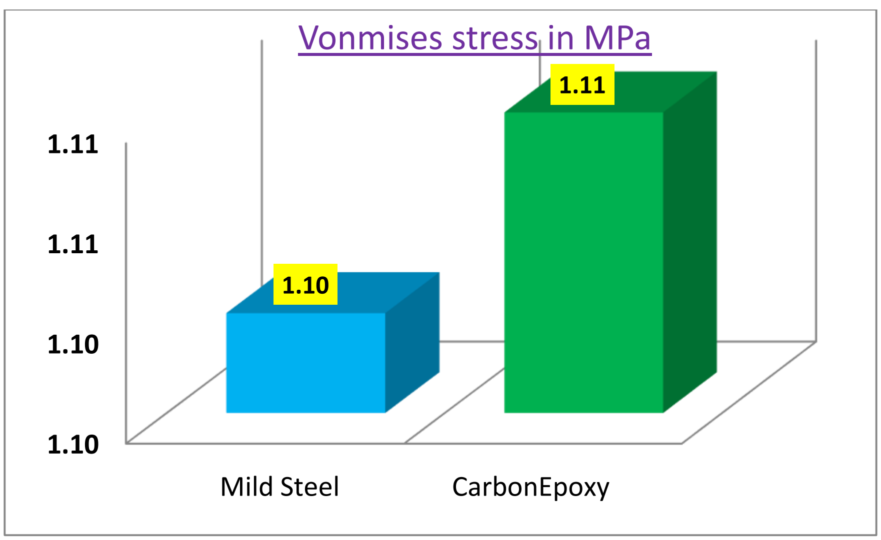


Von Mises stresses in assembly (Carbon Epoxy)

V. Result Comparison

The graphs shown below are comparative results of stress & strain deformation between mild steel and carbon epoxy pulley.

Maximum Deformation in Pulley assembly comparison Plot



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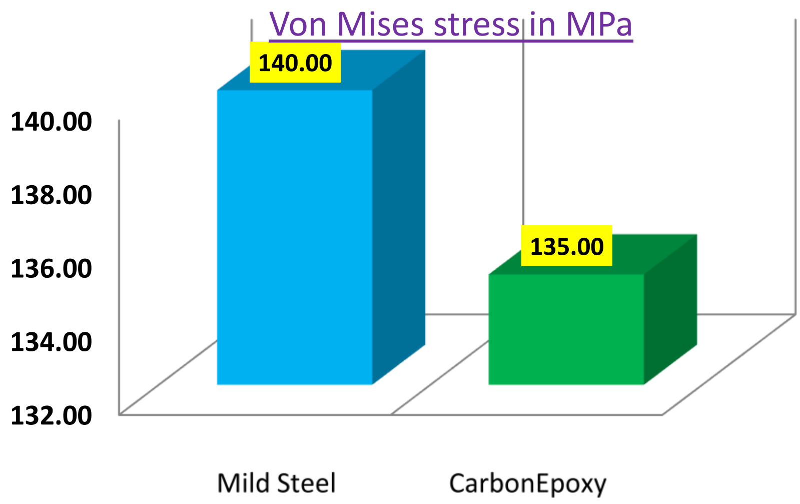
Maximum Von Mises stress in Pulley assembly comparison Plot



Mass Comparison

Mass of Carbon Epoxy Pulley is low compared to Mild steel Pulley.

Mass comparison table (in kg)

Components	Mild Steel	Carbon Epoxy
Drive Pulley	400	80
Shaft	210	40
Web	63	15
Rim	130	25

VI. CONCLUSION

Our Conveyor Pulley is of stable structure, reliable performance and long operating life. It can work normally in dusty, wet and muddy environment. Shaft connection methods better suited to the Carbon Epoxy we correctly favour using. An improved understanding of the component which determines the life of a pulley. Manufacturing techniques which are economical under our conditions. A more widespread appreciation of the cost of wear in our operations. Bearings of acceptable life-span.

- Carbon Epoxy has low mass of 40kg & low power consumption.

- The ability to control speed and thus the capacity has a major impact on line efficiency.
- It has easy line balancing and increased capacity.

REFERENCE

[1] CEMA: Belt Conveyor for Bulk Materials (4th Edition, 1994)

[2] MHEA: Recommended Practice for Troughed Belt Conveyors (1986)

[3] ANSI/CEMA B105.1-1992: Welded Steel Conveyor Pulley

[4] W.C.Young: Roark's Formula for Stress & Strain (6th Edition, 1989)

[5] J.W.Shigley: Mechanical Engineering Design (3rd Edition, 1981)

[6] Ringfeeder: Locking Assemblies RfN 7015 (1998)

[7] SKF: General Bearing Catalog (1994)