ISSN 2395-1621

# Design and Analysis of Belt Conveyor Roller Shaft

[#1]Harshavardhan A. Kadam, [#2]Nilesh S. Hyalij

[1]harshkadam4@gmail.com
[2]nilesh_hyalij@yahoo.com

[#12]Mechanical Engineering Department, Savitribai Phule Pune University, Pune, Maharashtra, India

**ABSTRACT**

**The aim of this paper is to study the existing Belt Conveyor System and Analyse of the Roller shaft at higher specification of motor to overcome the failure of belt conveyor Roller Shaft at higher inclination of belt conveyor system. Paper also involves Geometrical Model and Finite Element Modelling of Roller Shaft at lower and higher inclination. The geometrical modelling can be done by CREO Parametric and Finite Element Modelling done using ANSYS 14.1. Result of Linear static model and Transient Analysis of existing design and Analysed design at higher inclination with Design Failure Mode and Effective Analysis (DFMEA) are compared to prove which design is safe. In this Paper we work on Design of Roller Shaft and improve the life of Roller Shaft.**

**Keywords- Existing Roller Shaft, Analyzed Roller shaft with DFMEA**.

ARTICLE INFO

**Article History**

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

**Published online :**

**22nd November 2015**

## I. INTRODUCTION

As a kind of in house continuous transportation equipment, belt conveyor is widely used in today's modern port, especially in the transport of coal and mineral powder because of its high efficiency and environmental protection. Belt-conveyors are more acceptable than other means of transporting bulk materials; they neither pollute the air nor deafen the ears. Belt conveyor is one of the main transport equipment in coal mine, driving drum and belt is its key part. Friction principle is used to initiate mechanical drive for belt conveyor. So friction is the driving force. In order to raise transportation efficiency of belt conveyor, driving force of drum must be increased. Energy saving & efficiency, friction, fire & safety, maintenance and inspection are the other key factors of belt conveyor design. Most of the researchers focused on design modification to reduce the pulley (drum) and belt failures, maintenance cost, breakdowns, energy consumption and overall cost of the system for continuous transportation of material. The technologies used to reduce failures of the equipment and to increase the operational ability of the system the mechanisms like cam drive system, hydro-viscous soft start, magneto-rheological soft starter, Control strategy of disc braking system to be designed for efficient driving of belt conveyors. Most of technologies focused on Fatigue Failures of Welded Conveyor Drums, shell of drums and fracture analysis of collapsed heavy-duty pulleys and other typical failure analysis on pulley shafts by using finite element method. Conveyor Belt is a key part of belt conveyor system, sometimes its incorrect designing also make an important role in conveyor failure. Therefore belt Safety and Eco-design of non-metallic layer composites with a better capability of elongation should be considered. Transversal Vibrations and tension around a drive drum of a Conveyor Belt with a Low and Time-Varying Velocity are also considered. Control of whole system, operation & maintenance of belt conveyor and their inspection should be managed.

## I. LITERATURE REVIEW

[1]Vinod M. Bansode, Abhay A. Utpat present the paper on the Fatigue Life Prediction Of A Butt Weld Joint In A Drum Pulley Assembly Using Non-Linear Static Structural Analysis A failure analysis based on stress life approach may be useful for predicting the life time of weld in the structure. This study presents an upcoming methodology in new three dimensional Finite Element Model to calculate the fatigue life of weld. Ansys 12.1 simulation software uses stress-life method, based on a static non-linear Structural analysis. The weld material SN curves were experimentally determined by the Fatigue testing of the dumbell specimen as per 7608 standard. Thus the fatigue life prediction with the material curves from experimentation will give us more accurate and close to actual failure results**.** [2]X.Oscar fenn Daniel, A. Hussain lal

present the paper on Stress Analysis in Pulley of Stacker-Reclaimer by Using Fem Vs Analytical. The main aim of this project is to reduce the stress act on the shaft. This project leads to the stress optimization of the shaft. By producing a middle disc we reduced the stress developed on the shaft. So, that there is increase in shaft life. By applying various thickness of the middle disc we increase the life of the shaft. The load distribution on the shaft is even with the supporting discs. So, that we reduce the total load act on the particular contact on shaft. The main components are shaft, disc, cylinder, and hub. Designing units of this kind requires precise calculations of all loads in static conditions. In this paper the component cross section was analyzed. The stress analysis using Ansys is performed on the cross section of assembly of the reclaimer pulley considered as a reference for the existing design and even for the altered design which is the main task of this project. The cross section of the model was analysed with the simple loading conditions. With that the cylinder deflection is minimized in the cross section analysis. [3]Leo J. Laughlin presents the paper on Precision Pulley & Idler, US, describes the evolution of welded drum pulleys and their application in materials handling. This method of pulley construction is quite versatile as the manufacturer will burn an end disc from a steel plate and weld it to a standard hub. However, it also has its limitations, as the weld that joins the hub to the end disc is the most stressed point in the pulley. Pulley finite element analysis (PFEA) stress output of radial stresses in a welded hub-end disc pulley. PFEA analysis is developed by precision pulley & idler exclusively for drum pulley design. Even though this pulley has been designed as a mine duty pulley, with a life of 100,000 hours, the plot shows how the stresses are concentrated at the hub weld. This concentration of stresses is responsible for the majority of pulley failures. The shape of the weld plays an important part. The profile or bending of the weld to the end disc can dramatically affect the stress concentration factor at this critical junction.[4]Vinit Sethi and Lawrence K. Nordell presents the paper on the Modern Pulley Design Techniques and Failure Analysis Methods Published standards and specifications do not adequately cover engineered class pulleys for modern high strength steel cord belt conveyors. This paper discusses the Conveyor Dynamics, Inc. (CDI) design criteria and stress analysis techniques emphasizing the finite element method (FEM), fatigue failure criteria, design limits and manufacturing requirements to ensure successful and safe pulley installations.[5] Terry King Pr. Eng. Design Engineer to the Bosworth Group of Companies presents a paper on Belt Conveyor Pulley Design – Why the Failures. A system for the design and dimensioning of conveyor belt pulleys, in a manner which permits use at drawing office or computational level, is laid out. The theoretical model is used to explain the reason for some common failures and to place in context some of the pulley construction features seen in recent years. Lastly, an account is given of the factors which limit the life of a pulley and a design is proposed for the next generation of long-life, low cost pulleys for the South African market.

From the above Literature Review it is observed that Considerable research has been taken to develop the Analysis of different components of drum pulley like drum pipe, end-disk, bushes and shaft. So, as far as Design Failure Modes and Effects Analysis (DFMEA) is nit found in Literature has not be found for systematic, proactive method for identifying where and how it might fail.

## III METHODOLOGY

Methodologies used in different applications to reduce failures, maintenance cost and equipment related fatal accidents occurs during operation. The focus is on methodologies as Design modification, Drum and pulley failures, Belt design and its failure, energy & efficiency, friction, inspection, operation & maintenance and fire & safety.

An analysis of stress and impact when the impact load creates on roller shaft with the help of ANSYS when the angle is increased to 17 degree. To develop design for 17 degree belt conveyor roller shaft and create a model of the belt conveyor roller shaft with a bottom up approach. By using Design Failure Modes and Effects Analysis (DFMEA) for systematic, proactive method for identifying where and how it might fail.

Identify and fully understand potential failure modes and their causes, and the effects of failure on the system or end users, for a given product or process. Assess the risk associated with the identified failure modes, effects and causes, and prioritize issues for corrective action. Identify and carry out corrective actions to address the most serious concerns. A DFMEA is an engineering analysis done by a cross-functional team of subject matter experts that thoroughly analyzes product designs or manufacturing processes early in the product development process. Finds and corrects weaknesses before the product gets into the hands of the customer.

## IV DESCRIPTION OF COMPONENTS OF DRUM PULLEY

### *A ) Design Criteria's for Pulley Components)*

The stress criteria comprise of static and fatigue strength analyses. These stress criteria consist of setting limits on both the maximum stresses and on the stress range that can occur in different components of the pulley (shell, disk, hub and shaft).

The three dimensional stress fields consist of radial, tangential and axial stresses, which are analyzed in the pulley.

### *B) Static Strength Criteria*

While evaluating ductile materials, yield strength of the material is usually used as the failure criteria. In the case of brittle materials, like cast iron, which do not have a yield point, the ultimate strength of the material is used as the failure criteria. In general the Distortion Energy Theory for performing static strength analyses is used. This theory is meant for ductile materials as it predicts the initiation of yield. The Von Misses stress is used in the theory. For a tri-axial stress state, the Von Misses stress is defined in terms of the principal stresses as:

$$\sigma_{\text{von-misses}} = [0.5 * \{(\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2\}]^{0.5}$$

Principal stresses σ1, σ2 and σ3 are normal stresses that act on planes that do not carry any shear stress. Maximum and minimum principal stresses act on mutually perpendicular planes, and are the algebraically largest and algebraically smallest normal stresses to be found at a paint in a given stress field.

According to this theory, yielding occurs when the Von Misses stress equals the yield stress. Experiments have shown that the distortion-energy theory predicts yield with the greatest accuracy amongst the accepted stress theories. The design criterion uses the Distortion Energy theory with a multiplier of 0.7 which accounts for probabilistic conditions such as variations in metallurgy, metal porosity, inclusions, and other uncertain conditions. This multiplier of 0.7 is slightly higher than the 0.6 to 0.66 multiplier used for welded structures. Thus the maximum acceptable Von Misses' stress in the shaft, end-disk and shell is (0.7 X yield stress of the component).

*C) Fatigue Strength Criteria Shell*

In the case of most pulleys, the largest range stresses in the shell are usually in the tangential or hoop direction and occur close to the centreline of the pulley. Pulleys with wide shell faces may have the largest range stress in the axial direction due to bending in a region close to the shell/disk connection.

The British Standard BS5400 Part 10 is used to determine the allowable stress ranges for the circumferential and seam welds in the shell for infinite fatigue life as shown in Figure 2.

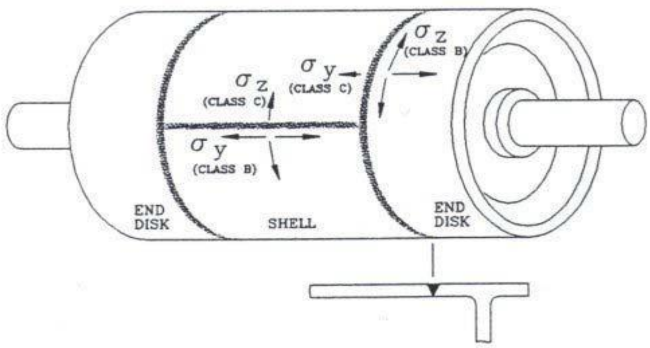


Fig. 1 Circumferential and Axial Weld Classifications

*D) Weld*

Shell Circumferential Welds have an allowable axial stress range of 77 MPa (11165 psi) (Class C weld) and allowable hoop stress range of 100 MPa (14500 psi) (Class B weld). These values apply if the welds are full penetration and have been ground flush and proven free of defects. If they are not ground flush and proven free of defects, the allowable axial stress range reduces to 55 Mpa (7975 psi) (Class D weld) and the hoop stress range to 77 MPa (11165 Ps)(Class C weld).

Shell Axial Seam Welds have an allowable axial stress range of 100 MPa (14500 psi) (Class B weld) and hoop stress range of 77 MPa (11165 psi) (Class C weld) if they are full penetration and have been ground flush and proven free of defects. If not, the allowable axial stress range reduces to 77 MPa (11165 psi) (Class C weld) and hoop stress range to 55 MPa (7975 psi) (Class D weld). These allowable stress ranges are for 10 million load cycles with a 97% confidence level. Radiographic and/or a full ultrasonic inspection must be performed to evaluate the welds.

For most pulleys, the largest fluctuating or range stresses in the disk are in the radial direction and are due to end-disk bending. The fatigue strength criteria used here is that the maximum stress should not exceed the endurance stress, Se, for infinite life. The endurance stress, Se is dependent on numerous factors including material type, surface finish, stress concentration effects, type of loading, failure mode, etc. A conservative endurance stress of 40% of yield stress (20% for shear) is used for ductile materials to account for the following possibilities, some of which are difficult to quantify:

• Unlimited number of starts and stops
• Dynamic loads
• Irregularities in lagging thickness
• Material buildup
• Overloading of the conveyor

*E )Shaft*

As the pulley rotates the shaft contact pressure under the locking device changes at the inside and outside shoulders. The alternating stress introduced due to this can lead to fatigue failure if the range is large. Therefore limits are placed on how large this range stress can be this range stress should not exceed the limits imposed in the modified Goodman diagram.

Fig. 2 Shaft Photo (Actual)

The shaft made up of Mild Steel Material EN8,9 Hard Material having length of 95 cm and keyway of 10cm by using milling operation at right side.

## V CAUSES OF FAILURE

- Bend Shaft used for drum so it will break.
- Bearing was fails so shaft corrupted on both sides.
- Also sometimes gear box moves to and fro or forward and backward motion then the shaft breaks suddenly.
- When the end disk weld of drum pipe and bushes weld are removed then shaft broken after some days.
- Depending on material of the shaft which is used for drum.

Fig 3. Failed Shaft

## VI NON-LINEAR STATIC STRUCTURAL ANALYSIS OF A DRUM PULLEY ASSEMBLY

Mathematically, the finite element method (FEM) is used for finding approximate solution of partial differential equations (PDE) as well as of integral equations. The solution approach is based either on eliminating the differential equation completely (steady state problems), or rendering the PDE into an equivalent ordinary differential equation, which is then solved using standard techniques such as finite differences, etc.

In solving partial differential equations, the primary challenge is to create an equation which approximates the equation to be studied, but which is numerically stable, meaning that errors in the input data and intermediate calculations do not accumulate and cause the resulting output to be meaningless. The Finite Element Method is a good choice for solving partial differential equations over complex domains or when the desired precision varies over the entire domain.

To perform an accurate analysis a structural engineer must determine such information as structural loads, geometry, support conditions, and materials properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and nonlinear behaviour.

Performing a Static Analysis

Following are the steps in brief to perform a static analysis:

1. Build Geometry
2. Define Material Properties
3. Apply Loads
4. Obtain Solution
5. Present the Results

### A) *Solid model details*

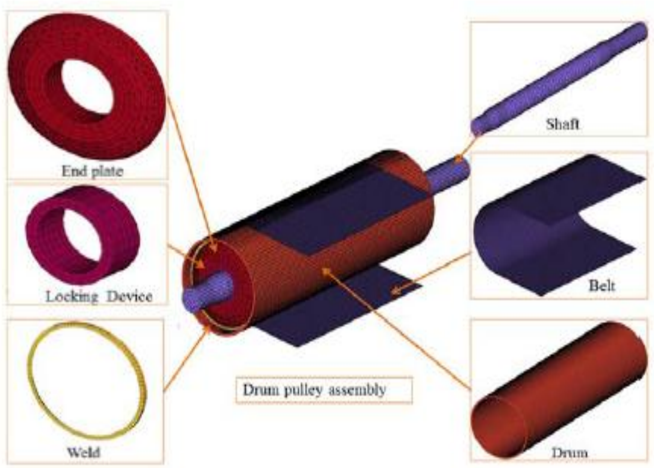


Fig4. Exploded view of meshed Drum Pulley Assembly

Shaft Dimension Return Roll Detail Part

1. Return Roll-Pipe Od-75x550 Length -53
2. Return Roll Shaft 22 Od 25x760 Length Io-22 Dia.
3. Return Roll Bearing 6204zz Qty-2 Nos
4. Return Roll Cap Od-82 Qty -2 Nos
5. J' Plate Qty-2 Nos

Table I
Shaft Material (Table)

| Sr No. | Description | Qty |
|---|---|---|
| 1 | Drum Pipe-10"X550 Lg (H & T End) | 2 |
| 2 | M.S.Plate Od-250x8 Thk (H&T End) | 4 |
| 3 | M.S.Pipe Od-80x65 Lg X 20 Thk (H&T End) | 4 |
| 4 | M-16 Nut & Bolt | 8 |
| 5 | M.S.Rod Dia.-50x810 Lg (Head End) | 1 |
| 6 | M.S.Rod Dia.-50x910 Lg (Tail End) | 1 |
| 7 | Bearing Ucp | 4 |
| 8 | Belt 20 Thk | 1 |

Table II
Material Properties of Components

| Component | E (GPa) | Poisson's Ratio | Syt (MPa) |
|---|---|---|---|
| Belt | 210 | 0.3 | |
| Drum | 250 | 0.3 | 410 |
| Weld | 210 | 0.3 | 350 |
| End disk | 197 | 0.3 | 335 |
| Bushes | 210 | 0.3 | 410 |
| Shaft | 210 | 0.3 | 340 |

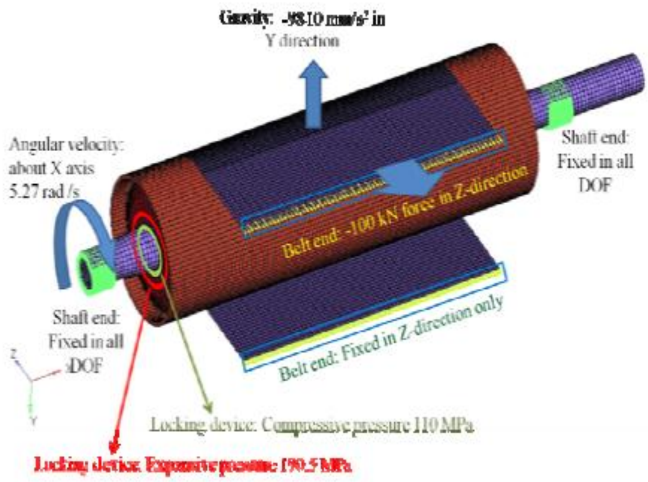


Fig 5. Boundary Condition

### B) *Result Interpretation*

Von misses stress= SEQV i.e. Equivalent stress

$$\sigma_v = \sqrt{\frac{[(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_x-\sigma_z)^2]}{2}}$$

 

Where, $\sigma_x$, $\sigma_y$, $\sigma_z$ are the corresponding stress in X, Y and Z directions.

The von mises criterion also known as the maximum distortion energy criterion, octahedral shear stress theory or Maxwell-Huber-hankey-von Mises theory, is often used to estimate the yield of ductile materials. The von Mises criterion states that failure occur when the energy of distortion reaches the same energy for yield/failure in uniaxial tension Mathematically, this Expressed as,

$$\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]<\sigma_y{}^2$$

This Equation Represents a principal stress ellipse as illustrated in the following Figure.

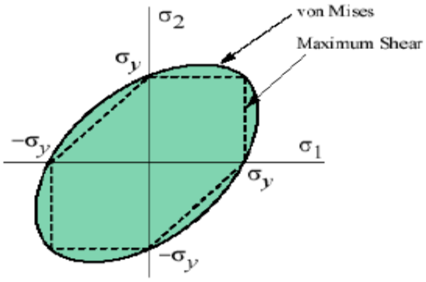


Fig 6. Von –Mises Criteria

Also shown on the Figure 6 is the maximum shear stress criterion (dashed line). This theory is more conservative than the von Mises criterion since it lies inside the Von Misses ellipse.

In addition to bounding the principal stresses to prevent ductile failure, the von Misses criterion also gives a reasonable estimation of fatigue failure, especially in cases of repeated tensile and tensile shear loading.

### *A) Result Deformation Plot*

Following figures are the Total Deformation Plots for different parts of the Drum Pulley Assembly.

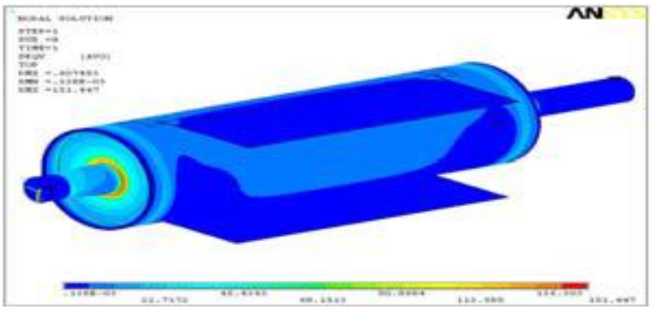

Fig 7.Stress Distribution for the total Assembly

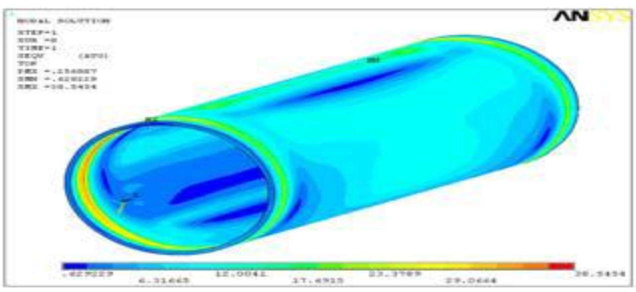

Fig 8.Stress Distribution in Drum

Fig 8. Stress Distribution in Weld

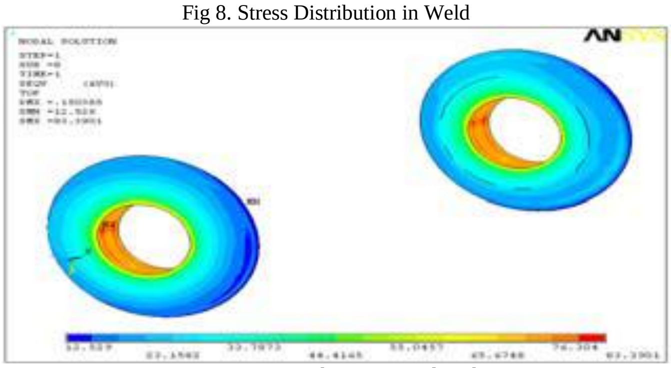

Fig 9. Stress Distribution in End Disks

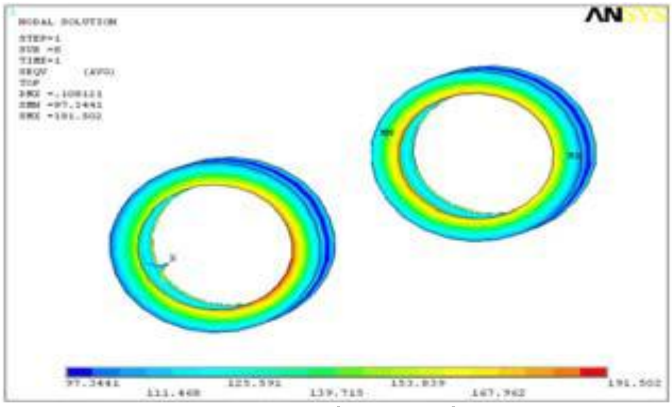

Fig 10.Stress Distribution in Bushes

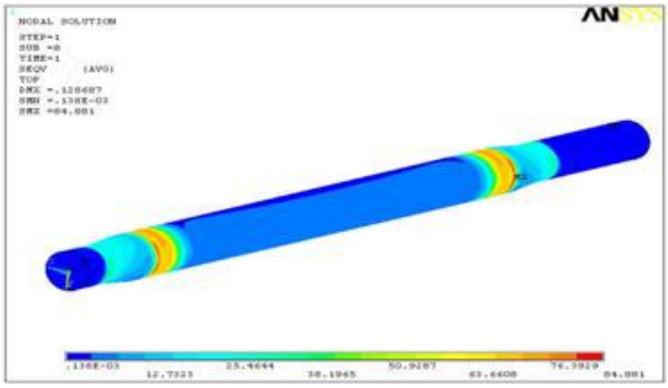

Fig 11.Stress Distribution in Shaft

### *B) Result Table*

Result table is prepared with the current design criteria for static strength and fatigue strength as discussed. On the basis of these criteria safe or failure limit is also discussed here.

 

Static strength criteria = 0.7 x Syt

Static strength criteria (for weld) = 0.6 x Syt

A fatigue strength criterion is given for life of 1 E +06 cycles with 97% confidence level.

Table III
Non-linear static structural analysis result Table

| Component Name | Von-Mises Stress | Static criteria | Fatigue Criteria | Static F.S. | Fatigue | Remark |
|---|---|---|---|---|---|---|
| Drum | 38.545 | 287 | 143.5 | 7.45 | 3.72 | safe |
| Weld | 46.919 | 210 | 55 | 4.48 | 1.17 | safe |
| End -Disk | 83.390 | 234.5 | 134 | 2.81 | 1.61 | safe |
| Bushes | 191.502 | 300 | 280 | 1.57 | 1.46 | safe |
| Shaft | 84.884 | 238 | 143.5 | 2.80 | 1.69 | safe |

## VII CONCLUSIONS

By observing the causes of failure are material of the shaft, end disk, bushes and gear box. So, to overcome these failures we used the predictive maintenance and design modification. By using the ANSYS software we analyse the stresses and impact on shaft at higher inclinations we will made changes in design accordingly.

## VIII FUTURE WORK

We focus to reduce drum and pulley failure, design modification and predictive maintenance of each. An Analysis of stresses and impact load on roller shaft with the help of ANSYS 14.1 at higher inclination and develop design for 17 to 18 degree.

## REFERENCES


1. VINOD M. BANSODE, ABHAY A. UTPAT "Fatigue Life Prediction of A Butt Weld Joint In A Drum Pulley Assembly Using Non-Linear Static Structural Analysis" Dept. of Mechanical Engineering, College of Engineering, Pandharpur, India.
2. X. Oscar fenn Daniel, A. Hussain lal "Stress Analysis in Pulley of Stacker-Reclaimer by Using Fem Vs Analytical" Department of Mechanical Engineering, JJ College of Engineering and Technology, Tiruchirappalli. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X PP 52-59.
3. Leo J. Laughlin "Precision Pulley & Idler US, describes the evolution of welded drum pulleys and their application in materials handling" www.ppipella.com.
4. Vinit Sethi and Lawrence K. Nordell "Modern Pulley Design Techniques And Failure Analysis Methods" conveyor Dynamics, Inc.1111 West Holly Street Bellingham, WA 98225.
5. Terry King Pr. Eng "Belt Conveyor Pulley Design - Why the Failures?" B.Sc Mech. Engineering (Hons.) Design Engineer to the Bosworth Group of Companies.
6. Devendra Kumar, R.K. Mandloi "Analysis & Prospects of Modification in Belt Conveyors - A Review" IJERA Vol.3, Issue 1, January -February 2013, pp.581-587.
7. Gys van Zyl, Abdulmohsin Al-Sahli "Failure analysis of conveyor pulley shaft" Materials and Corrosion Section, SABIC T&I, Jubail, Saudi Arabia ,Received in revised form 27 April 2013.
8. Jairo A. Martins and István Kövesdy "Overview in the Application of FEM in Mining and the Study of Case: Stress Analysis in Pulleys of Stacker-Reclaimers: FEM vs. Analytical" http://dx.doi.org/10.5772/46165.
9. G Styger and R F Laubscher "An Investigation into the Effect of the Manufacturing Process on The Fatigue Performance Of Conveyor Pulleys" Faculty of Engineering and the Built Environment Mechanical Engineering Science Auckland Park Kingsway Campus Weir Minerals Africa 31 Isando Rd. Isando University of Johannesburg.


 