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Experimental Analysis of Stress, Strain and deformation on different types of Conveyor belt pulleys. An analysis conducted at Visakhapatnam Steel Plant

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ABSTRACT

Conveyor pulleys play an essential role in the performance and reliability of belt conveyor systems worldwide. It is because of this essential role that pulley selection becomes a critical process in keeping equipment up and running. If selection is conducted in haste, a conveyor pulley may be inadequately sized and selected, leading to premature pulley failure and costly downtime.

INTRODUCTION

Conveyor Pulley Basics:

Conveyor pulleys are designed for use on belt conveyor systems as a means to drive, redirect, provide tension to, or help track the conveyor belt. Conveyor pulleys are not designed for the same application intent as conveyor rollers. Conveyor rollers are designed to be used in the bed of a conveyor as a support for the conveyed product and often under the conveyor bed in the return section to support the return side of the conveyor belt.

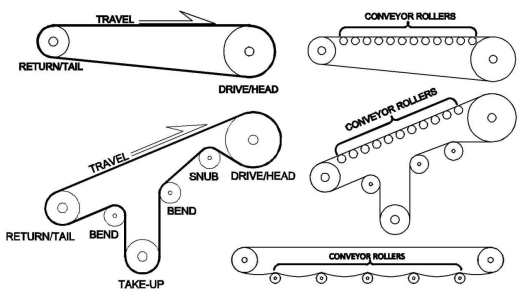

Fig. 1: Showing the various arrangements and types of conveyor pulleys used in material handling.

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2. Terminology of conveyor pulley:

Pulley/Core Diameter – The outside diameter of the cylindrical body of a conveyor pulley, without coating.

Finish Diameter **–** The outside diameter of a coated pulley (core diameter + 2 times the coating/wrap thickness).

Face Width – The length of a pulley’s cylindrical body. This area is intended to act as the contact surface for the conveyor belt.

Wall/Rim Thickness– The initial thickness of the tube, pipe, or formed plate that makes up the cylindrical body of the pulley.

End Disks – The plates welded on the ends of a pulley which act as the medium between the hub and rim.

Crown/Profile– A change in the shape of the pulley face designed for the purpose of enhancing belt tracking.

Shaft/Axle – The mounting mechanism for the pulley assembly**.**

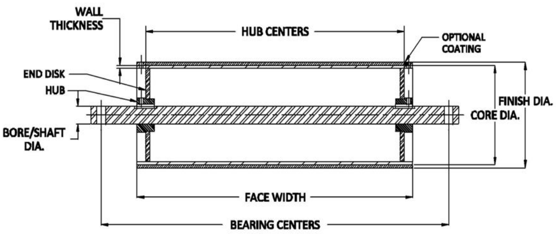

Fig. 2: Showing the various terminology and nomenclature of the conveyor pulley.

Hub – The point of connection between the shaft and end disk or pulley wall.

Bore Diameter – The inner diameter of a pulley at the point where the shaft is inserted

Bearing Centers – The distance between the center lines of each bearing race in which a pulley is mounted.

Hub Centers – The distance between the center line of each hub contact surface.

Safety Factor – The capacity of a system or component to perform beyond its expected load

Shaft Deflection:

The single largest contributor to premature failure of conveyor pulleys is end disk fatigue caused by excessive shaft deflection. Shaft deflection is the bending or flexing of a shaft caused by the sum of the loads on the pulley. The sources of these loads include belt tension, product load and the weight of the pulley itself. Excessive shaft deflection occurs as a result of an undersized shaft. The drawing below illustrates the concept of shaft deflection.

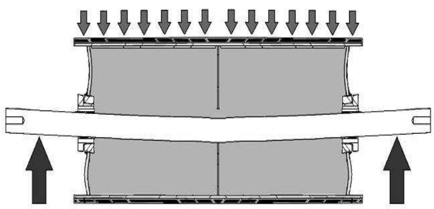

Fig. 3: Showing the Excessive shaft deflection occurring as a result of an undersized shaft (exaggerated for effect).

Excessive shaft deflection occurs when shaft diameter is improperly sized for the demands of an application. Although it may appear as a potential solution, selecting a shaft material with greater strength characteristics will have virtually no effect on its stiffness as it pertains to shaft deflection. The Modulus of Elasticity, which is a physical property of a substance which describes its tendency to deform elastically when a force is applied to it, remains virtually the same across all grades of steel, and because of this, the only proper way to increase the stiffness of a steel conveyor pulley shaft is to increase its diameter.

Premature failure of a conveyor pulley is not likely to occur from an oversized shaft, but an undersized shaft can produce harmful and destructive results. The Conveyor Equipment Manufacturers Association (CEMA) recommends that shaft be designed with a maximum bending stress of 8000 psi or a maximum free shaft deflection slope at the hub of 0.0023 inches per inch.

Shaft Alignment When Using Compression Style Hubs:

When installing bushings and a shaft into a pulley with compression style hubs, the desired result is to locate the bushing face such that it is fixed on a plane parallel to the hub face. Since three points define a plane, having three or more retaining bolts in the hub/bushing assembly is ideal for maintaining this alignment. Compression style systems which utilize a minimum of three equal spaced bolts (XT® for example, uses a minimum of 4) will generally keep the bushings in acceptable alignment with the mating hubs by allowing even pressure to be applied all the way around the circumference of the bushing. The parallel alignment of the hub and bushing faces will keep the shaft extension perpendicular to the hub face and help to maintain its concentricity with the pulley. Maintaining shaft alignment when using hub and bushing systems with only two retaining bolts (such as Taper-Lock® sizes K12 – K30) can prove to be difficult. The two bolts utilized in these designs are located 170° apart (as opposed to 180°) which causes additional pre-stress on the shaft by creating a moment arm around the center line of the shaft. The moment arm makes the shaft more likely to bend toward the 170° side of the angle which is already weakened by the split in the bushing being located on this side. These reasons are why XT® hubs & bushings are preferred and Taper-Lock® style hubs & bushings are not recommended for use in two hub pulley configurations.

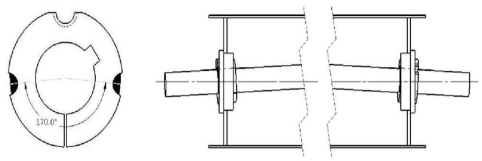

Fig. 4: Showing the typical taper-lock bushing.

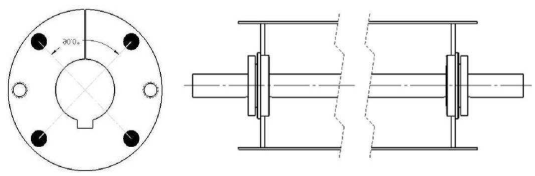

Fig. 5: Showing Typical Pulley Assembly.

3. Shaft Alignment & Maximum Circular Runout:

Shaft alignment affects how much runout can be measured on a conveyor pulley assembly (for additional information on measuring runout, see STEP#9). Selection of a hub style should take into account how likely it will be to maintain shaft alignment upon installation of the bushings. Since maintaining shaft alignment with Taper-Lock® systems is difficult, the runout measured on the final pulley assembly is typically greater. Considering this, a pulley manufactured with XT® hubs & bushings will have a more desirable maximum circular runout than a similar pulley manufactured with Taper-Lock® hubs & bushings.

4. Theoretical Stress Calculation For Conveyor Pulley:

The following readings were taken from the conveyor pulley and mathematical calculations are done as follows.

Carrying side Belt Tension, T_1 = 27.11 KN
Return side Belt Tension, T_2 = 10.55 KN
Co-efficient of Friction, μ = 0.45
Wrap Angle in radians, α = 3.6652
Belt Width, B = 1200 mm
Diameter of Pulley, D = 630mm
Shell Thickness after machining, t = 12mm

Active drive arc, $\theta = \dfrac{\log\frac{T_1}{T_2}}{\mu} = \dfrac{\log\frac{27.11}{10.55}}{0.45}$ = 0.9108 radians

Equivalent tension, $T_e = \dfrac{T_1}{\mu\alpha\left(1-e^{\mu\theta}\right)} + T_2\left(1-\dfrac{\theta}{\alpha}\right)$

$$= \frac{27.11}{0.45*3.6652\left(1-e^{-0.45*0.9108}\right)} + 10.55\left(1-\frac{0.9108}{3.6652}\right)$$

Te = 56.8102 KN

Pressure, $Z_b = \frac{2*T_e}{B*D} = \frac{2*56.8102*1000}{1200*630}$

$Z_b = 0.1503$ MPa

Stress, $S_b = \frac{Z_b*D}{2*t} = \frac{0.1503*630}{2*12} = 3.9454$ Mpa

5. Results of the experiment using ANSYS:

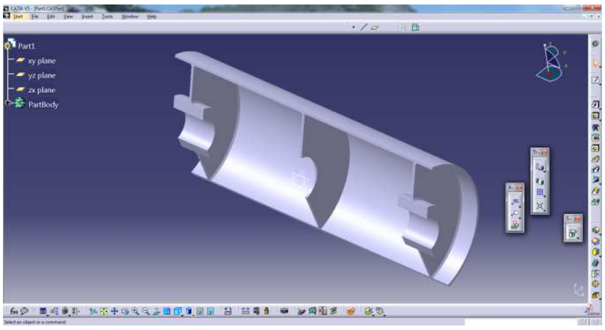

Fig. 6: showing the Half Section View Of Existing Conveyor Pulley With T Shaped Hub.

Table 1: showing the results of parabolic shaped hub pulley.

Material	Total Deformation	Stress	Strain	Factor of Safety
Steel	0.015772	3.6871	1.84e-5	4.67
Aluminium	0.04472	3.7175	5.24e-5	4.45
Brass	0.031817	3.7296	3.73e-5	4.29
Cast iron	0.028545	3.6712	3.34e-5	2.9

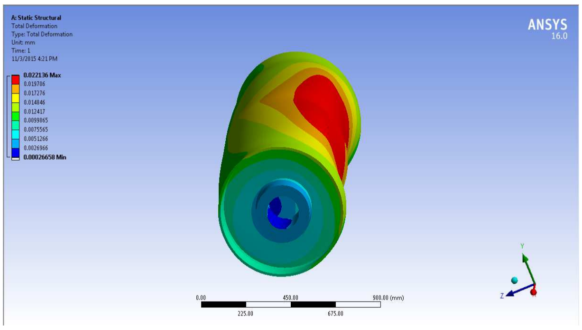

Fig. 7: showing the deformation in the pulley.

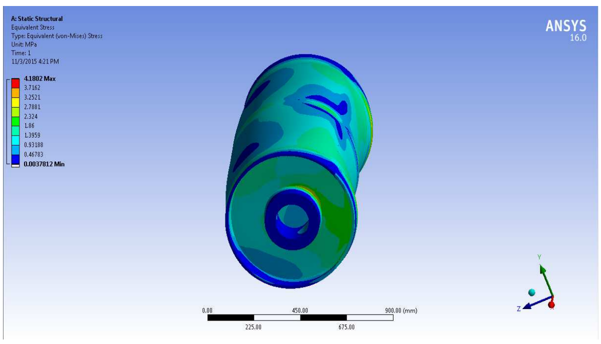

Fig. 8: showing the stress in the pulley.

Conclusion:

The present work design and vibration analysis of conveyor pulley was done at Visakhapatnam Steel Plant.

Total observation, design calculation and analysis is performed at steel plant. Here the finite element method applied in the work was based on numerical modeling and facilitated designing different hub support for conveyor pulley with various materials.

Analysis with changing hub support of pulley is an efficient way of improving fatigue life.

It has become key question to design pulleys.

Finite element model was developed for conveyor pulley to study the influence of hub support, stresses and deformation.

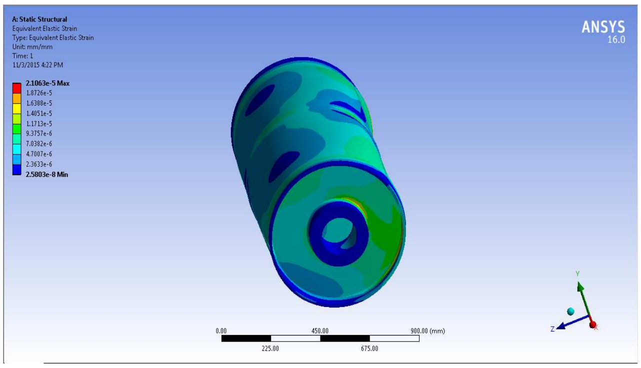

Fig. 9: showing the strain in the pulley.

Table 2: showing the results of T shaped hub pulley.

Material	Total Deformation	Stress	Strain	Factor of Safety
Steel	0.022188	4.0506	2.03e-5	4.25
Aluminium	0.032873	4.0831	5.75e-5	4.05
Brass	0.044717	4.0961	4.10e-5	3.9
Cast iron	0.040161	4.0339	3.67e-5	2.65

It was found that the material selection has influence on the conveyor pulley with light weight.

Steel material has minimum deformation and all material stresses are at near value.

Parabolic shaped hub support is an effective design to reduce stresses.

With the information from the analysis, steel pulley with parabolic shaped hub was proposed as the optimum pulley**.**

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