Design and Analysis of Inclined Belt Conveyor System for Coal Loading for Weight Reduction

Utkarsh Kamble, Shubham Paturkar, Pooja Swami, Shivam Malwade, M. S.Dholkawala, Anand Bhise

Abstract: Belt conveyor is used for the transportation of material from one location to another. Belt conveyor has high load carrying capacity, large length of conveying path, simple design, easy maintenance and high reliability of operation. This paper discuss about study of design procedure and analysis of inclined type belt conveyor system for coal loading application.[1] The paper shows design calculations of conveyor, trajectory of the material on conveyor, power and belt design and stresses on pulley due to belt tensions at and slack and tight side. The results comprises of capacity, power calculations on pulley, stress analysis on pulley drive shaft, on components of belt conveyor and its effect. The Belt conveyor used for coal processing industry is considered to have a design capacity is 250 TPH and speed of the conveyor to be 115 ft. /min. Geometrical modelling has been done using Catia V5R20 and finite element analysis is done in Solid works 2018. This paper discusses the conveyor design and weight optimization. Material weight reduction is accomplished using ASHBY charts and ASME standards and finally weight optimisation and performance index has been discussed.

Keywords: Inclined Belt Conveyor, Ashby chart, Performance index, Weight Optimization, Analysis, modelling

I. INTRODUCTION:

Belt conveyor is most populous equipment in such system to achieve material flow from start to end point. Belt Conveyor system is also used in material transport in foundry shop like supply and distribution of molding sand, moulds and removal of waste. This paper provides to design the conveyor system used which includes belt speed, belt width, motor selection, belt specification, shaft diameter, pulley, gear box selection, with the help of standard model calculation.[1] During the project design stage for the transportation of raw materials or finished products, the choice of the method must favour the most cost-effective solution for the volume of material moved; the plant and its maintenance; its flexibility for adaptation and its ability to carry a variety of loads and even be overloaded at times.

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II. LITERATURE SURVEY:

The belt is moved by the electric power. The belt conveyor improves the efficiency and also prevents the drawback of the roller conveyor mechanism.
Belt conveyor consists of two or more pulleys, with a continuous loop of material. One or both of the pulleys are powered, moving the belt and thus moving the coal forward. The powered pulley is a drive pulley while unpowered is idler. In industry there are two types of bel conveyor one is used for material handling (for transporting Agriculture materials) and the other one is used for transporting bulk material. Performance index is crucial for material selection, using the ASHBY standards and its chart, material is filtered. It was found that Titanium alloy has less self-weight than AISI-4340 by 47.36%, however AISI-4340 was found to be having less deflection and stress conditions as compared to Titanium alloy. Also Titanium alloy has high performance index as compared to any other material proving to be optimum for the given design consideration. As far as cost consideration AISI-4340 is available at lower cost as compared to the Titanium alloy as per the requirement of end user.

III. PROBLEM STATEMENT:

The following design specifications for the belt conveyor system has been assumed for analysis in the presented paper: Belt conveyor of inclined type, having design capacity 250 TPH for coal processing industry. Also selection of appropriate material to fit a FoS of 10 to 13. Speed of the conveyor will be 115 ft. /sec, with vertical travel of 15.6 ft. And study of stress analysis on conveyor shaft.
Additional Inputs:

Bulk Material Density, (DEN) =80 lbs/ft^3

Bulk Material Repose Angle, (X) = 15 deg

Belt Width, (W) = 20 in

Belt Speed, (S) = 115 ft/min

Idler Angle, (Y) = 45 deg

Edge of Pile to Edge of Belt, (G) = 1.0 in

Edge of Idler to Edge of Belt, (H) = 0.6 in

A1, A2, A3 are respective areas as shown in Figure 1.

Centre of Gravity (CG1, CG2)= 3.44 and 7.11 in respectively.

Centre of Gravity of bulk material(CGma)= 4.3 in

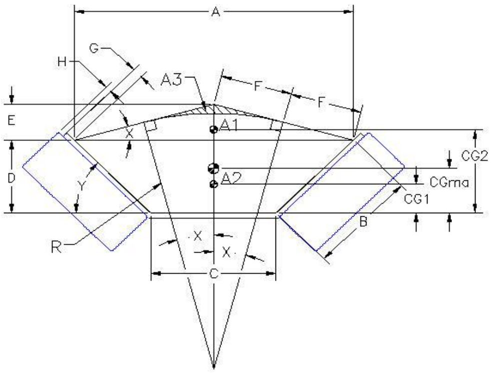

Figure 1: Capacity Calculations

Calculations:

- Capacity:

1. Belt Conveyor Weight Capacity,

(TPH) = $\frac{volume\ capacity * Material\ Density * 60}{2000}$

$= \frac{105*80*60}{2000}$

2. TPH = 251 tons/hr

- Trajectory:

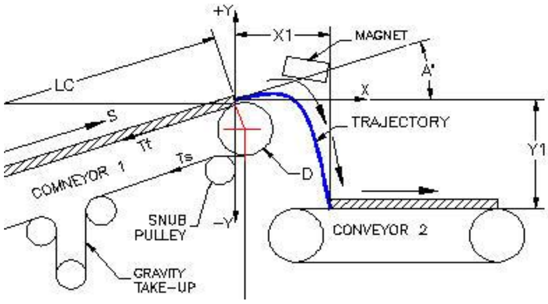

Figure 2:Trajectory of material

Tension in tight side (Tt)

Tension in slack slide (Ts)

Length of conveyor (LC)

Angle of inclination (A)

1. Distance travelled horizontally,

(X1) = $\frac{S * \Delta t * \cos A}{60} = \frac{115*1*\cos 15}{60}$

X1 = 1.85 ft.

2. Distance travelled vertically, (Y1)

Y1 = $\frac{115*\Delta t*\sin A}{60} - \frac{9.81*\Delta t^2}{2}$

Y1 = -15.6 ft.

- Power Calculations:

Conveyor drive efficiency, (e) = 80%

Loading chute factor, (Fc) =1.1

Start acceleration factor, (Fs) = 1.15

OUTPUTS: -

Minimum conveyor motor power,

(P) = $\frac{Force*Velocity}{3300}$

$$(P) = \frac{Fc * Fs * T * S}{e * 33000}$$

P = 50 hp

T= Equivalent Tension in conveyor belt

- Shaft Diameter Calculations:

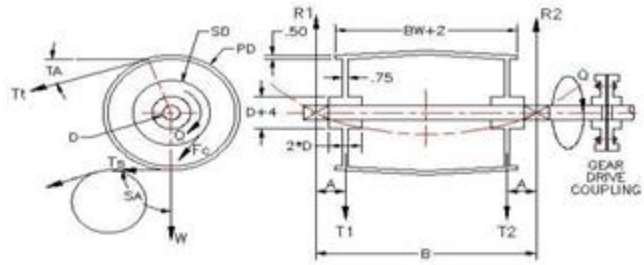

Figure 3:Sectional view of shaft assembly

Conveyor belt tight side tension Tt = 3048 lbs
Conveyor belt slack side tension Ts = 902 lbs
Slack side angle of belt SA = 90 deg
Tight side angle of belt TA = 15 deg
Pulley diameter PD = 30 in
Distance between bearing and pulley (A) = 8 in
Distance between bearings B = 40 in
Belt width BW = 20 in

ASME Code[4]

The ASME Code equation for power shafting diameter D is:

$$D^3 = \frac{16}{\pi * Ss} * [(Kb * Mb)^2 + (Kt * Mt)^2]^{0.5}$$

Allowable shear stress: Ss = 8000 lbs/in^2 for shaft without keyway.

Allowable shear stress: Ss = 6000 lbs/in^2 for shaft with keyway.

This allowable stress Ss applies to commercial steel shafting and takes into account the effects of fatigue.

The bending shock, Kb and torque shock, Kt load factors are given below.

Mb is the applied bending moment and Mt is the torque at the same point on the shaft.

Table 1:Shock factors for loadings

For rotating shafts	Kb	Kt
Gradually applied load	1.5	1.0
Sudden(minor) loading	1.5-2.0	1.0-1.5
Sudden(heavy) loading	2.0-3.0	1.5-2.0

Allowable Stress (Ss) = 6000 lbs/in^2
Bending Moment (Mb) = 20300 in-lbs
Kb= 2.0, Kt= 1.5, Torque (Mt) = 722 in-lbs

D_{min} = **3.251 in**

Material Selection:

The material selection is done using the Digital Logic Method, the process is as follows:

1. Screening of material on the basis of 4 parameters namely Function(to bear bending and torsional load), Objective(To reduce weight), Variable(density and area), Constraint(Force and length)
2. Selection of property chart. ASHBY charts are used for selecting the family of materials, it is done on the basis of Objective of the part.
3. Again based on objective a performance index is finalised using the specific formulas given by ASHBY charts, which is then used for calculating the slope (θ).
4. Using the slope a line is marked on the selected property chart and then all the families are selected that fall on the line.
5. After this using ASM standards the composition of materials is selected. These are called candidate materials.
6. ASME standards are used to compare properties of candidate materials like after heat treatment process.

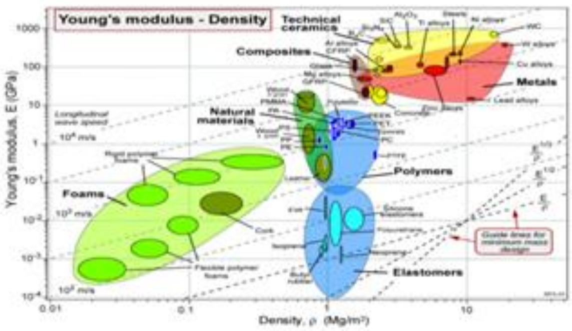

Figure 4: Ashby Chart

7. Table no 2 shows the candidate materials along with their calculated performance index comparing various properties related for the design of the belt conveyor:

Table 2: Performance Chart

MATERIAL	PERFORMACE INDEX
S304	54.57
IS2062	53.55
CARBON STEEL 1020	57.44
PLAIN CARBON STEEL-1020	58.456
C1045	57.89
45C8	69.89
40C4	56.83
AISI-4340	87.53
AL ALLOY 2024-T6	35.4
TI ALLOY-6AI-4V	77.33
ALUMINIYM 601	22.96
AISI-4140	58.77
AISI-1020	54.37

8. It is clear from the Table no 2 that the most suitable material for this design is **AISI-4340** with a performance index of 87.53.
9. Followed by Ti Alloy (performance index 77.33) and 45C8 (performance index 69.89).
10. Following are the 4 basic parameters that were used for the selection of the material:

Table 3: Screening Process

Material Screening	
Function	To support bending and torsional loading
Objective	To reduce mass and increase strength
Constraint	Length, Force
Variable	Density, cross sectional area

Finite Element Analysis

Analysis is done on the components of the Belt conveyor designed in the CATIA V5R20 using the Solid works 2018.The components were subjected to different loads to check the failure of the geometric model.

- Following are the results of the analysis on the drive shaft: Considering AISI 4340 material the maximum stress acting is 56 MPa with a weight of 19.29 kg.

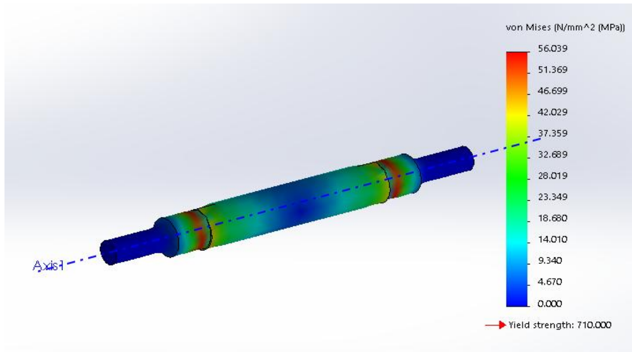

Figure 5: Stress analysis of AISI 4340

The maximum deflection in the drive shaft is 0.027 mm.

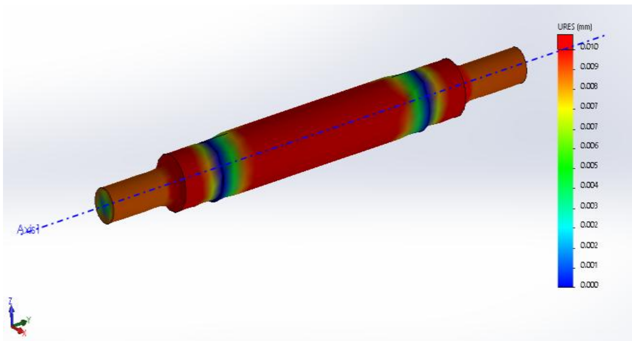

Figure 6: Deflection in AISI 4340

The minimum Factor of Safety is found out to be 12.6.

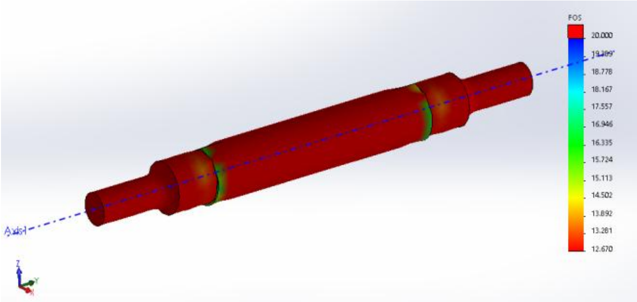

Figure 7:Factor of Safety for AISI 4340

Considering other materials we get the following comparable values:

Table 4: Comparison of Results of candidate materials

MATERIAL	WEIGHT OF SHAFT	MAX STRESS	MINIMUM FOS	DEFLECTION
IS2062	18.9077 kg	56.065 N/mm^2	4.21	0.028 mm
PLAIN CARBON STEEL-1020	19.3251 kg	56.065 N/mm^2 (MPa)	6.59	0.026 mm
45C8	19.276 kg	56.065 N/mm^2 (MPa)	9.98	0.027 mm
AISI-4340	19.276 kg	56.039 N/mm^2 (MPa)	12.67	0.027 mm
TI ALLOY-6Al-4V	10.8751 kg	56.046 N/mm^2 (MPa)	14	0.053 mm

As Titanium alloy gives very significant weight reduction, here are the results of analysis for Titanium alloy.

Stress analysis:

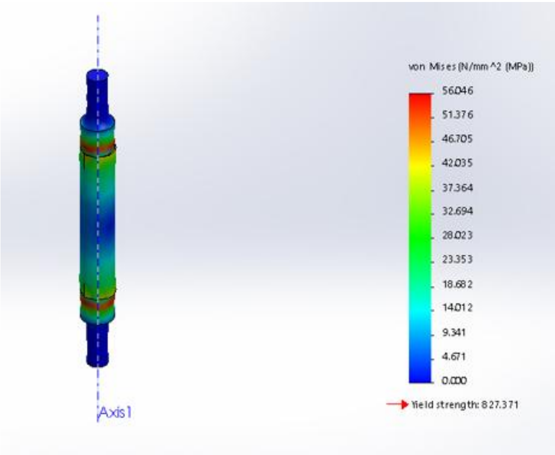

Figure 8:Stress analysis for Ti Alloy

The maximum deflection of the drive shaft is 0.053 mm.

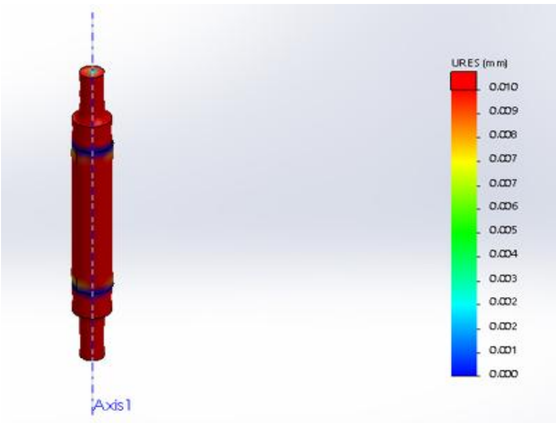

Figure 9: Deflection in Ti Alloy

And the minimum Factor of safety offered is 14.76.

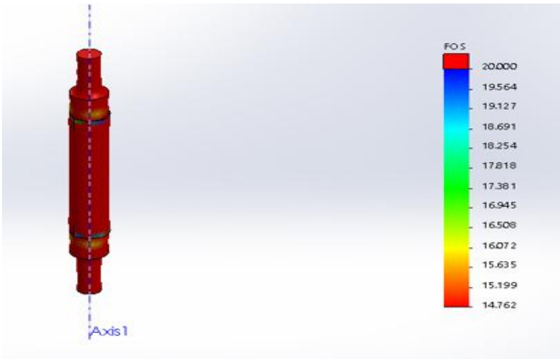

Figure 10:Factor of Safety in Ti Alloy

Hence this material is also supporting the load, the only drawback is that this material is costlier than the other chosen material i.e. AISI 4340.

- Considering the Idler Roller Assembly we have the following results with AISI 4340:

The maximum stress developed is 86 MPa.

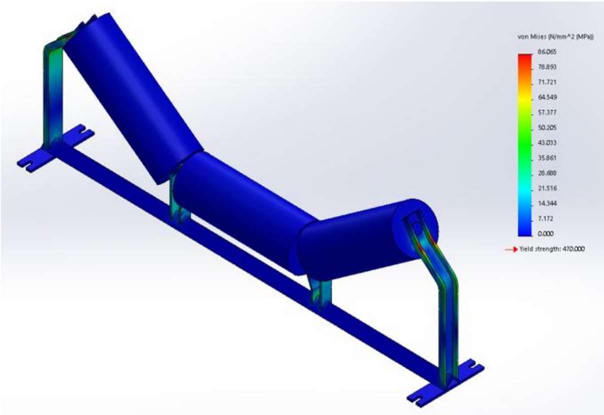

Figure 11: Stress Analysis in AISI 4340

Maximum deflection of the assembly is 0.171 mm.

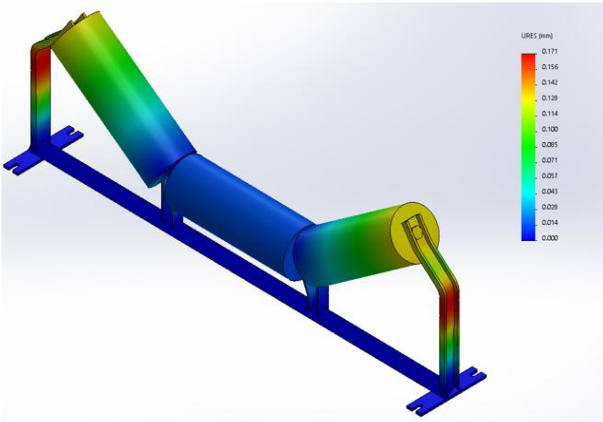

Figure 12:Deflection in AISI 4340

IV. CONCLUSION

- From the Table of comparison of results given above, with those results, it can be inferred that Titanium Alloy material gives a considerable weight reduction to the system with supporting all the loadings.
- Ti alloy is very costlier than the other material with a higher performance index.

- Ti alloy also it exceeds the required range of factor of safety that is from 10 to 13 and hence the material neglected.
- Thus, due to the requirements AISI-4340 is thus the most suitable material for specified conditions if there were no such condition Ti alloy can be the most suitable material for the system with respect to weight reduction.
- From this paper we can also see the process to effectively select a material for any loading conditions or any other applications.

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AUTHORS PROFILE

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