DESIGN AND OPTIMIZATION OF IDLER FOR BELT CONVEYOR

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Abstract— The work present in this paper focuses on the reduction of cost of idler as belt conveyor consist of many idler and reducing running cost of conveyor system by optimizing by. i) Selecting optimum diameter of shell, ii) selecting optimum diameter of shaft. iii) Thickness of shell. iv) Distance between two bearings. Modeling and Analysis of parts of idler is done by using ‘Finite Element Method’.

Keywords: Idler; cost of idlers; Optimizing of idler.

I. INTRODUCTION

Conveyors are a powerful material handling tool. Using conveyor systems is a good way to reduce the risks of musculoskeletal damage in tasks or processes that involve manual handling, as they reduce the need for cyclic lifting and carrying. They offer the opportunity to improve productivity, reduce product handling and damage, and minimize labor content in a manufacturing or distribution facility. Conveyors are generally classified as either Unit Load Conveyors that are designed to handle specific uniform units such as cartons or pallets, or Process Conveyors that are designed to handle loose product such as sand, gravel, coffee, cookies, etc. which are fed to machinery for further operations or mixing. It is quite common for manufacturing plants to combine both Process and Unit Load conveyors in its operations. Roller conveyor is not subjected to complex state of loading even though we found that it is designed with higher factor of safety. If we redesigned critical parts e.g. Roller (Idler), Bearing & Frame etc then it is possible to minimize the overall weight of the assembly.

Idler is the supporting device for belt and cargo of a belt conveyor. Idlers move as the belt moves so as to reduce the running resistance of the conveyor. Idlers’ qualities depend on the usage of the belt conveyor, particularly the life span of the belt. However, the maintenance costs of idlers have become the major part of the conveyor’s operating costs. Hence, idlers need to have reasonable structure, durability in use, small ratio of steering resistance, reliability, and dust or coal dust cannot get in bearing, due to which the conveyor has a small running resistance, saves energy and prolongs the service life. [6]

Powered belt conveyors are considerable long as compared to roller conveyor. So we can achieve considerable amount of material saving if we apply above study related to roller conveyor to this belt conveyor to ‘Finite Element Method’ which is used to carry out the stress analysis.

II. TERMINOLOGY OF ELEMENTS

Schematic display of the mechanical elements of a belt conveyor.

III. IDLER

Idlers are used on a belt conveyor to support the belt on the carrying and return strands. Carrying idlers also support the load in transit along the conveyor. There is an array of idlers available on the market for the use on conveyors in different applications. Some examples of the different types of idlers available are shown below.

Types of idlers:

Idlers can be divided into trough idlers (Figure 1), flat idlers (Figure 2), impact idlers (Figure 3) and centering idlers (Figure 4) according to the function.

Fig. 1: Schematic of conveyor belt. [28]

Fig. 2: Troughing idler

Fig. 3: Flat idler

Fig. 4 : Impact idler
A. IDLER SPACING
The spacing or pitch of idlers has a direct impact on the sag of the belt between the idler sets. The idlers on the carrying side of a conveyor must support both, the belt and the load carried by the belt and on the return side, the idlers must support only the empty return belt.

![Image of idler](image)

**Fig. 5**: Centering idler

B. General concept of Design
While designing the main component of the roller, it must be borne in mind that majority of component are designed as per calculation, some are determined empirically and/or by experience only. The main components are i) Roller diameter, 2) RPM of roller, 3) Shaft diameter, 4) Size of shell of roller, 5) Bearing capacity.

Diameter of roll and shaft are inter-related in calculating an optimum idler design, because they directly affect the bearing life. Therefore the initial criteria for selection will be:

(a) Roll diameter
(b) Bearing life
(c) Shaft deflection

Changing the roller diameter from lower to higher the power reduction will be more according to difference of diameter.

Indention Power Reduction : 
\[ 1 - \left( \frac{d_1}{d_2} \right)^{2/3} \]

C. Bearing life
To calculate the bearing life, the actual load on the bearing is computed from the table and check up whether the chosen bearing would give the anticipated life for the application[17,3]

\[ \text{Hence life of bearing} = \left( \frac{D}{L} \right)^3 \times 10^6 \text{ revolutions} \]

\[ \text{From the formula} \quad V = \frac{\pi DN}{60} \quad [26] \]

\[ \text{Life of bearing in hours} = \frac{\text{life of bearing in revolutions}}{(\text{speed of bearing in RPM}) \times 60} \]

D. Shaft Deflection
The acceptable shaft deflection is governed by the amount of deflection which the outer and inner races of the bearing can be deflection without resulting in a substantial decrease in bearing life.

![Image of deflection](image)

**Fig. 7**: Loading condition due to total load [3]
The formula used to calculate the angular deflection is:
\[ \text{Angular Deflection} = (\text{minutes}) \]
\[ (P \times C \times I/4 \times E \times 1) \times \left( \frac{180 \times 60}{\pi} \right) \]

Where:
- \( C \) = dimension from bearing to reaction point (m)
- \( P \) = Total load acting on roller
- \( I \) = modulus of elasticity (210 Gpa for steel)
- \( J \) = moment of inertia of the shaft (m^4) = \( \pi (d/64)^4 \)
- \( d \) = shaft diameter (m)

By substitution the formula may be simplified to:
\[ \text{Angular Deflection} = \left( 0.08373 \times P \times C \times I \right) / d^4 \]

Where the units of dimensions \( C, P \) and \( d \) are now in mm
- Thus the factors influencing shaft deflection are the shaft diameter and the distance between bearing and support point.
- Increasing the shaft diameter is the simplest method of reducing deflection.
- The distance between the support point and roller face is normally determined by applicable specifications like the roll end design.
- Thus the “c” dimension is largely dependent on the design of the sealing system utilized for bearing protection, and should be minimized on the basis of allowing sufficient space for the installation of an efficient sealing system.
- The permissible angular misalignment between outer and inner races, which will not produce inadmissibly high additional stresses in the bearing, depends on the radial internal clearance of the bearing during operation, the bearing size, its internal design and the forces and moments acting on it.

Bearing manufacturers quote the following limits:-
Effective belt width used for conveying material is ABCD area "BEGJC". The load acting on side roller is defined by considering troughing idler is used in conveyor in general use:

- Deep Groove Ball Bearings is 6 minute
- Seiz Resistant Bearings is 10 minutes \(^{[10]}\)

### E. Calculation of the load on idler roll

Considering troughing idler is used in conveyor system. Troughing idler are of two types

1. Equal roller, which have all roller of equal size,

2. Unequal roller which have middle roller smaller than other roller. The load distribution will be different according to angle of troughing. Actual load on the middle idler depends upon angle of troughing. It is seen that middle roller of unequal rollers is smaller than equal roller. Total load acting on middle roller is 50 to 70 percentage of total load. To distribute load equally on each roller unequal roller is preferred.

![Rollers for troughing idler (equal or unequal)](image)

The load acting on the middle roller is defined by area “BEGJC”. The load acting on side roller is defined by area “A’EFB”, which is less than the middle roller.

Effective belt width used for conveying material is ABCD = (0.9W – 50) mm as per DIN 22101

### F. General theoretical Design guidelines

All belt conveyors shall be designed according to the applicable guidelines (DIN, CEMA, ANSI). From experience, see some initial characteristics of bulk material, density, physical conditions etc.

### G. Belt speed

A number of factors should be considered when determining the correct conveyor belt speed. They include the material particle size, the inclination of the belt at the loading point, degradation of the material during loading and discharge, belt tensions and power consumption.

### H. Belt width

- Belt width shall not be less than 800 mm, for special applications 650 mm belts may be used. In packing plants 500 mm flat belts may be applicable.
- The minimum belt width for reversible conveyors shall not be less than 800 mm.

#### I. Belt conveyor sub system design guidelines

1) Idler design

- Trough angle shall not be less than 30°.
- Carrier and return idler diameter shall be designed according to DIN (15207-1 /22107) or CEMA (Class C) or equivalent, (bearing life L10 = 60,000 h at 500 rpm), guaranteed idlers failure less than 2% replacement per year, within 5 years after commissioning.

#### General design calculation of idler

<table>
<thead>
<tr>
<th>1 Determine Load acting on Idler (P)</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>A. Static Load (Ps) ((Wm+WB) \times Lc \times x \times g)</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>B. Dynamic Load (Pd) (Ps \times Sf \times Lf \times B10f)</td>
<td>N</td>
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<table>
<thead>
<tr>
<th>2 Determine Roller Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Length of Roller (Br) ((2 \times \text{Side margin:0.075m}) + B)</td>
</tr>
<tr>
<td>B. Reactions at end of Roller (RA=RB)</td>
</tr>
<tr>
<td>C. Bending Moment at A (Ms) (P \times Br/2)</td>
</tr>
<tr>
<td>D. Section Moduls of shaft (Zr)</td>
</tr>
<tr>
<td>E. Roller Inner Diameter (Dii) (\left(\frac{Zr \times P \times Dii}{2 \times Br}\right)^{1/4})</td>
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<table>
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<tr>
<th>3 Determine Shaft Size</th>
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<tbody>
<tr>
<td>A. Reactions at end of shaft (RA=RB)</td>
</tr>
<tr>
<td>B. Bending Moment at A (Ms) (RA \times L)</td>
</tr>
<tr>
<td>C. Section Moduls of shaft (Zs)</td>
</tr>
<tr>
<td>D. Shaft Diameter (d) (\left(\frac{32 \times Zs}{pi} \times \pi)^{1/3})</td>
</tr>
<tr>
<td>E. Length of Shaft (Br+2 \times (0.075))</td>
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Table 2: General design calculation of idler
It has been observe that life of bearing is affected by size of roller, so in order to access maximum life of bearing & to minimize deflection in the present design.

J. Finite Element Analysis

Finite element analysis (FEA) has become commonplace in recent years, and is now the basis of a multibillion dollar per year industry. Numerical solutions to even very complicated stress problems can now be obtained routinely using FEA, and the method is so important that even introductory treatments of Mechanics of Materials.[23]

K. Analysis type

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure’s response are assumed to vary slowly with respect to time. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

A static structural analysis can be either linear or nonlinear. All types of nonlinearities are allowed - large deformations, plasticity, stress stiffening, contact (gap) elements, hyper elasticity and so on. This chapter focuses on linear static analyses,

L. Procedure of Finite Element Analysis

In practice, a finite element analysis usually consists of three principal steps[25]

per–processing, Analysis & post processing.
3 D Solid Modeling is done in Pro-e creo Software. Shaft is fixed at end as it works as axel. Uniform Distributed Load is given on the roller. The tetra hadron mesh is used. Triangle element is used for better result. Analysis is done in Ansys 12.0.
Fig. 11: meshing of part

M. Analysis

The dataset prepared by the pre-processor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations.

\[ K_{ij}u_j = f_i \]

Where \( u \) and \( f \) are the displacements and externally applied forces at the nodal points. The formation of the \( K \) matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA’s principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

Post processing:

In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. A typical postprocessor display overlay colored contours representing stress levels on the model, showing a full field picture similar to that of photo elastic or experimental results.

IV. Conclusion

From the design & analysis of roller it is seen that from the above it could be seen that for equal rollers, the theoretical absolute of bearing life in hours is less than unequal roller. But the actual life would depend upon a number of factors like:

1. Total number of continuous working hours per day per shift.
2. Environmental factor – Temperature of working.
3. Quality of the bearing itself – like: basic material, manufacturing methods, tolerance.
4. The impact force due to height of fall and lump size.
5. The shape of material.
7. The way in which the rollers are loaded and unloaded in trucks/wagons, etc.
8. Sealing System.

Hence, if we are able to attain a life between 30,000 hours to 50,000 hrs from this rollers, which are life time lubricated for high speed and high capacity conveyors, it is really admirable. For roller shaft subjected to dynamic loading, the deflection caused by the load is considered to be the most critical factor. Deflection is also maximum on the shaft of the central roller which carries 2/3 of the load. When the deflection is more than the permissible, it leads to – misalignment of bearings & increase maintenance cost of the parts.

Finite element modeling was also used to investigate the problem of insufficient stiffness in the idler roller. The FEA modeling shows that an roller could have its stiffness significantly increased with only a small increase in the overall weight of the roller.

From FEA it can be seen that as thickness of shell increase von misses stress & deformation decreases. For end cover plate as thickness of end cap increases von misses stress & deformation decreases. While decreases in shaft diameter von misses stress & deformation increases. So for better life we can select lesser diameter of shaft larger diameter of shell & lesser distance between two bearings.

REFERENCES

[1] Ishwar J Mullani - Engineering Science and Application design for belt conveyors
[13] Shalom Akhail , Harpreet Singh Department of Mechanical Engineering , Department of Mechanical Engineering,"Design optimization for modification of trough belt conveyor to reduce material spillage used in cinder transport in cement plant”ijert E-ISSN: 2321–9637
[15] Allen V Reicks, Belt conveyor idler roll behavior”
[16] Mr. A. Frittella, Frankenwald South Africa “Mathematical Selection Criteria with particular reference to the influence of additional loads”13th February 1991
[18] Honghong Chen, Savonia University of Applied Sciences, Business and Engineering, Varkaus


[25] Dima Nazzal, Ahmed El-Nashar “Survey of research in modeling conveyor-based automated material handling systems in wafer fabs”


[27] Glideseal Idler Roller Product Catalogue Shalom Akhai1, Harpreet Singh2 “Design optimization for modification of trough belt conveyor to reduce material spillage used in clinker transport in cement plant”, 1 Undergraduate Student, Department of Mechanical Engineering- IJART Volume 1, Issue 4, November 2013