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Design and Analysis of Shaft for Roller Conveyor with Different Materials

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Abstract - *A shaft is an important component of a roller conveyor. This study is focused on adapting an efficient and cost-effective shaft material for roller conveyor so as to meet required conditions.In this study mild steel shaft is compared with stainless steel shaft. Mild steel contains 0.25% of carbon and stainless steel contains 1.2% of carbon. These properties can be improved by adding different alloying elements such as nickel, molybdenum, titanium, etc. Mild steel contains carbon as the alloy whereas stainless steel includes chromium which makes stainless steel high corrosion resistance and a surface which does not stain or tarnish.In hollow shaft, the material at the center is removed and spread at large radius. Therefore, hollow shafts are stronger than solid shaft having the same weight*.

***Key Words*: Roller conveyor, shaft, mild steel, stainless steel, alloying elements.**

1. INTRODUCTION

A roller conveyor system is a common machine of mechanical handling equipment that moves materials from one location to another. They are actually a series of rollers supported within a frame where objects can be moved either manually, by gravity, or by power. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Manykinds of conveying systems are available in the market, and are adapted according to the various needs of different manufacturing industries. There are chain conveyors (floor and overhead) as well. Chain conveyors consist of enclosed tracks, I-Beam, towline, power & free, and hand pushed trolleys. Conveyor systems are used widespread across a range of industries due to the numerous benefits they provide. Roller conveyors are classified into two groups according to the principle of conveying action. These are:

1. **Unpowered or Idle Roller Conveyor:** In an unpowered roller conveyor, the rollers are not driven or powered from an external source. The material or heavy boxes, etc. roll over the series of rollers either by manual push or push from an dogs, rods or clamps. Generally these conveyors operate at horizontal plane, but at times a gentle slope is given to these conveyors to aid motion of the loads. An inclination of 1.5% to 3% ensures that the load will roll by gravity. Such conveyors are termed "gravity roller conveyor'.

Fig. Roller conveyor (Chain Type)

2. **Powered or Live Roller Conveyor:** In a live roller conveyor, all or a selected number of rollers are driven by one or a number of motors (if necessary) depending on the selected drive arrangement. The driven roller transfers the motion to the loads by friction. The live roller conveyors may be installed at a slightly tilted position, up to 10° up or upto 17° down. The load can be moved in either directions by changing the direction of rotation of the rollers, where these are called reversing conveyors.

2. LITERATURE REVIEW

Nazzal et al., (2007)[4] conducted the study on Survey Of Research In Modeling Conveyor-Based Automated Material Handling Systems In Wafer Fabs. This paper discusses literature related to models of conveyor systems in semiconductor fabs. A comprehensive overview of simulation-based models is provided. We also identify and discuss specific research problems and needs in the design and control of closed-loop conveyors. It is concluded that new analytical and simulation models of conveyor systems need to be developed to understand the behavior of such systems and bridge the gap between theoretical research and industry problems.

Abbas et al., (2004)[9] studied the Investigation into Design and Manufacturing of Mechanical Conveyors Systems for Food Processing. This paper presents a application of concept of concurrent engineering and the principles of design for manufacturing and design for assembly, several critical conveyor parts were investigated for their functionality, material suitability, strength criterion, cost and ease of assembly in the overall conveyor system.

The critical parts were modified and redesigned with new shape and geometry, and some with new materials. The improved design methods and the functionality of new conveyor parts were verified and tested on a new test conveyor system designed, manufactured and assembled using the new improved parts. The improved methodology for design and production of conveyor components is based on the minimization of materials, parts and costs, using the rules of design for manufacture and design for assembly.

Results obtained on a test conveyor system verify the benefits of using the improved techniques. The overall material cost was reduced by 19% and the overall assembly cost was reduced by 20% compared to conventional methods.

Taylor et al [5]. studied the availability modeling of powered Roller Conveyers. This paper provides an analysis of the reliability and availability of two common designs of the line-shaft roller conveyor. The first is a standard design in which each roller is belted directly to a spinning line shaft under the conveyor. The second is a new design in which only one top roller is belted to the line shaft, and all other rollers are belted to the one powered roller in a series arrangement. The main reason for this design is that the upper belts are faster to replace than belts connected to the line shaft, thus increasing system availability. However, the latter design is less reliable in that the failure of a single belt may lead to multiple roller failures.

Sekimoto et al[1], conducted the study on Development Of Concept Design CAD System. In order to shorten the product development time and improve the product quality, 3 dimensions at CAD/CAE system is essential. It is necessary to develop a system which utilizes the concept design data at the early stage for the whole process of the product development. The purpose of this project is to improve the product quality by the sufficient design study iteration at the early stage of design. A CAD system which can be used for the concept design and an appropriate CAD environment should be developed. And another purpose is to shorten the product development time at the late stage of design.

3. DESIGN OF SHAFT

3.1 Shaft

Shaft is a common and important machine element. It is a rotating member, in general, has a circular cross-section and is used to transmit power. The shaft may be hollow or solid. The shaft is supported on bearings and it rotates a set of gears or pulleys for the purpose of power transmission. The shaft is generally acted upon by bending moment, torsion and axial force. Design of shaft primarily involves in determining stresses at critical point in the shaft that is arising due to aforementioned loading. Other two similar forms of a shaft are axle and spindle.

Standard sizes of shafts

Typical sizes of solid shaft that are available in the market are,

Up to 25 mm - 0.5 mm increments

25 to 50 mm - 1.0 mm increments

50 to 100 mm - 2.0 mm increments

100 to 200 mm - 5.0 mm increments

3.2 Material for Shaft

The ferrous, non-ferrous materials and non-metals are used as shaft material depending on the application. Some of the common ferrous materials used for shaft are discussed below.

1. **Hot-rolled plain carbon steel:**

These materials are least expensive. Since it is hot rolled, scaling is always present on the surface and machining is required to make the surface smooth.

Cold-drawn plain carbon/alloy composition:

Since it is cold drawn it has got its inherent characteristics of smooth bright finish. Amount of machining therefore is minimal. Better yield strength is also obtained. This is widely used for general purpose transmission shaft.

2. **Alloy steels:**

Alloy steel as one can understand is a mixture of various elements with the parent steel to improve certain physical properties. To retain the total advantage of alloying materials one requires heat treatment of the machine components after it has been manufactured. Nickel, chromium and vanadium are some of the common alloying materials. However, alloy steel is expensive. These materials are used for relatively severe service conditions. When the situation demands great strength then alloy steels are used. They have fewer tendencies to crack, warp or distort in heat treatment. Residual stresses are also less compared to CS(Carbon Steel). In certain cases the shaft needs to be wear resistant, and then more attention has to be paid to make the surface of the shaft to be wear resistant.

3.3 Design Considerations for shaft

Shafts are designed on the basis of strength or rigidity or both. Design based on strength is to ensure that stress at any location of the shaft does not exceed the material yield stress. Design based on rigidity is to ensure that maximum deflection (because of bending) and maximum twist (due to torsion) of the shaft is within the allowable limits.

In designing shafts on the basis of strength, the following cases may be considered:

a) Shafts subjected to torque
b) Shafts subjected to bending moment
c) Shafts subjected to combination of torque and bending moment
d) Shafts subjected to axial loads in addition to combination of torque and bending moment.

Shafts subjected to torque:

Maximum shear stress developed due to torque is given by following formula,

$$\tau = \frac{T\,r}{J} \leq [\tau]$$

Where,T= Twisting moment ,

J= Polar moment of inertia of shaft about the axis of rotation

$= \frac{\pi d^4}{32}$ for solid shaft

$= \frac{\pi(d_0^4 - d_i^4)}{32}$ for holloe shaft with d_0 and d_i as outer and inner diameter.

r= Distance from neutral axis to the outer most fibre=

d/2 or d_0

So dimensions of the shaft subjected to torque can be determined from above relation for a known value of allowable shear stress.

Shafts Subjected to Bending Moment:

Maximum bending stress developed in a shaft is given by,

$$\sigma_b = \frac{M\,y}{I} \leq [\sigma_t]$$

Where, M = Bending Moment acting on the shaft,

I = Moment of inertia of cross-sectional area of the shaft about the axis of rotation

$= \frac{\pi d^4}{64}$ for solid shaft with diameter d

$= \frac{\pi(d_0^4 - d_i^4)}{64}$ for hollow shaft withd_0 and d_i as

Outer and inner diameter.

y = Distance from neutral axis to the outer most fibre = d/2 or $d_0/2$

So dimensions of the shaft subjected to bending moment can be determined from above relation for a known value of allowable tensile stress.

Shafts subjected to Combination of Torque and Bending Moment:

When the shaft is subjected to combination of torque and bending moment, principal stresses are calculated and then different theories of failure are used. Bending stress and torsional shear stress can be calculated using the above relations.

$$\tau = \frac{16T}{\pi d^3}$$

$$\sigma_b = \frac{32M}{\pi d^3}$$

4. EXPERIMENTAL STUDY

Fig4.1. Universal Testing Machine

Fig4.2 Load control Unit

The experimental conformation for testing various stresses on UTM (Universal Testing Machine) is as given –

1. The conformation and usage are given in the method, published by a standard organization. This identifies clearly the sample preparation, fixturing, gauge length (the length which is under study or observation), analysis, etc.

2. The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held.

3. After the machine starts working it begin to apply an increasing load on specimen. During the tests the control system and the digital unit (computerized unit) of the machine record the load and extension or compression of the specimen.

4. Generally these UTM Machines ranges from very small loadings to the ones with over 1,000 KN capacities.

Procedure

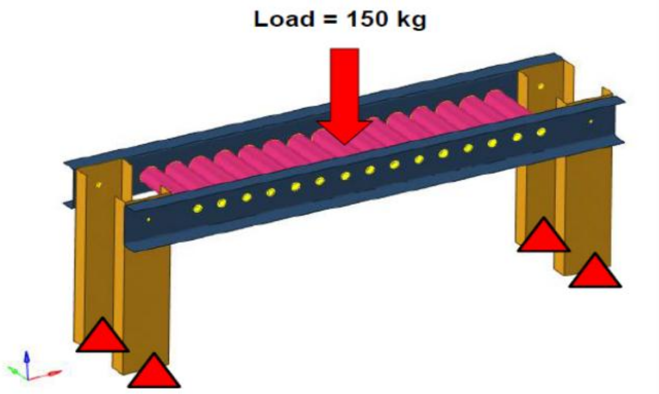
The operation Procedure for experimental testing on UTM (Universal Testing Machine) is as below –

1. Make sure that all the switches and main switches are put on. Ensure that release valve and the control valve mounted on the control unit are closed.
2. Move the middle crosshead of loading unit up and down with the help of mechanical motors; there by the space from upper crosshead and middle crosshead decreases or increase, this helps us to adjust the gap between crossheads as per length of the specimen.
3. Now put the machine on and open the control valve slowly.
4. Observe the upward movement of upper and lower crosshead. The middle crosshead will remain stationary. One can control the movement speed of crosshead using control valve.
5. As soon as the control valve is opened note down the changes on load dial/display along with displacement dial/display. The values for load will increase for some time and the remain stationary but the value for displacement will go on increasing. This load value is nothing but the dead weight of lower crosshead.
6. Now make the load reading zero with the help of tare switch. Shut down the machine. Close the control valve and open the release valve. Note the backflow of hydraulic oil and observe slow lowering of the crosshead.
7. The value for load will decrease for some time and then become negative and the values for displacement will go on decreasing. This is termed as adjustment is not done properly.
8. Put the timber specimen between middle and lower crosshead. Ensure that there is a small gap within crosshead and the specimen.
9. After selecting suitable range on load dial gauge close the release valve and slowly open the control valve.

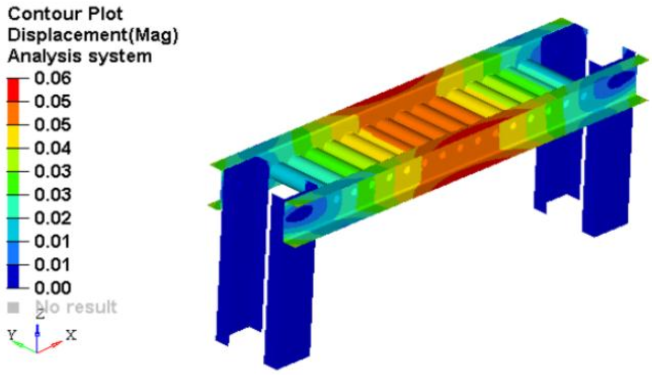
5. RESULTS AND DISCUSSION

In this project work we used hyper mesh and optistruct software for required results. The different loads are applied on shafts and we got the following results.

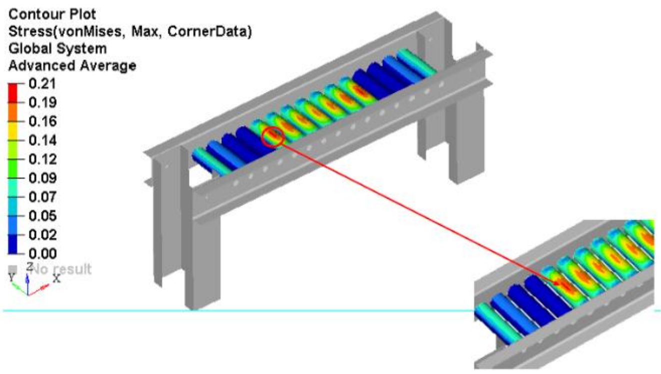
Load and boundary condition 150 Kg



5.1 Displacement plot for stainless steel



5.2 Stress plot for stainless steel



Similar procedure is used for obtaining displacement plots and stress plots for load conditions given i.e.180Kg and 210Kg.The values of practical readings are not precise due to poor fabrication work so we take the analytical results. The final values of displacement and stress values are given below:

Load	Result summary	
	Displacement(mm)	Stress (Mpa)
150 Kg	0.06	0.21
180 Kg	0.07	0.25
210 Kg	0.08	0.29

From the above readings we ensure that the values of displacement and stress induced on the shafts are increasing as the load values increases for stainless steel shaft.

6. ANALYSIS OF ROLLER CONVEYOR SHAFT FOR DIFFERENT MATERIAL

In this study, we used mild steel shaft in comparison with stainless Steel shaft for roller conveyor system. By using hyper mesh and optistruct software the following comparisons are made:

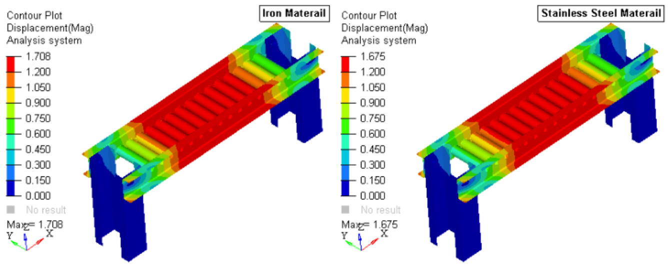


Fig6.1. Estimated displacement plot

The maximum displacement for mild steel shaft is 1.708 whereas for stainless steel material is 1.675.

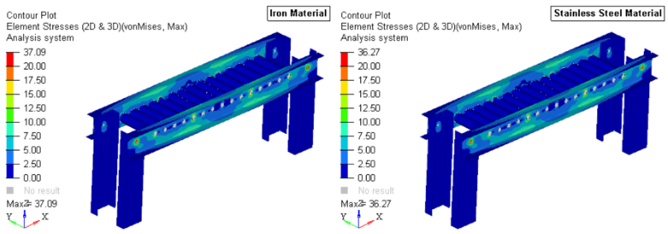


Fig6.2. Estimated stress plot

The stress values of mild steel and stainless steel material shaft are37.09 and 36.27Mpa respectively.

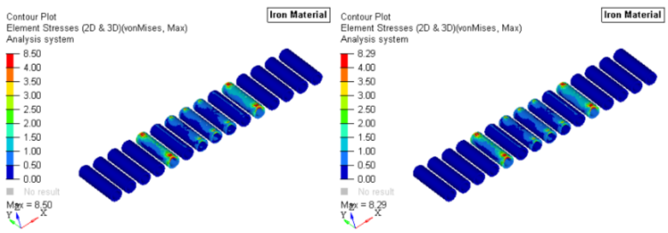


Fig6.3. Estimated stress plot for iron and stainless stress

From the above static analysis we found that there is difference

In the total weight of the roller conveyor assembly. Therefore it is beneficial to use stainless steel material for shafts of roller conveyor than mild steel.

Material	Iron	Stainless steel
Weight of roller conveyor (Kg)	238.7	233.6

7. CONCLUSIONS

In this study we used iron material shaft and stainless steel material and specified the readings of analytical results and conclude that the material reduction with same strength and

Working properties.

1. The stresses developed in the iron material shaft is much more than it is developed so that the material which is suitable for the Shafts of a roller conveyor than iron or mild steel.

2. Though value of deflection, stress is more in case of Optimized design, but it is allowable.

3. The existing system will be redesign and optimize for weight, resulting into material saving by modifying and analyzing the critical conveyor parts.

4. It is possible to change the number of driven rollers shafts in a quick and easy manner depending on the new user requirements.

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