Design and Analysis of Discharging of Dust in Pneumatic Conveying System by a Screw Conveyor Shafts

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Abstract— Conveyors are equipment that is used for moving material from one position to another position. There are many types of conveyor machines available in market such as Belt conveyor, Roller conveyors and Screw conveyors. Belt conveyor is driven by electric motors and other moving parts. We can find belt conveyor in factories, warehouses and public transportation centres. It helps us to moving boxes and bulk quantity material handling.

Before the advent of modern automation techniques, factory workers often have to travel from project to project, but due to belt conveyor it is easy to move, it saves workers time, stress, physical efforts and it allows project to come to the worker, instead of the worker to project.

These roller conveyors are available in both belt and chain driven model. Portable conveyors these conveyors are movable it can be adjusted according to the product and its need.

The history of the screw conveyor—one of man’s simplest and most efficient tools for the conveying of bulk materials can be traced back more than 2,000 years to ancient Greece and the development of the "Archimedean Screw."

A screw conveyor or auger conveyor is a mechanism that uses a rotating helical screw blade, called a "flighting", usually within a tube, to move liquid or granular materials. They are oftenly used by industries due to compact and economical for some feeding rates hence it is used as variable rate feeder by many industries.

A proper designing of the screw conveyor will affect its efficiency, working and lifespan. For design purpose, estimating the factors that will affect the manufacturing of screw conveyor, determining the capacities of conveyor, determining the shaft calculations, power calculation, checking of diameter for required lump, suitable bearings are studied.

Modelling of the screw conveyor and analysing the shaft of conveyor by using designing software and analysis software are done.

Keywords— Design and Analysis of Screw Conveyor by using Different Design Software’s like Pro-e, Ansys, and Fem

I. HISTORY OF SCREW CONVEYOR

The history of the screw conveyor—one of man’s simplest and most efficient tools for the conveying of bulk materials can be traced back

More than 2,000 years to ancient Greece and the development of the "Archimedean Screw."

Fig. 1: Image of screw conveyor used in ancient time

Archimedes designed the first screw conveyor in the third century B.C. It was used for removing water from ships and for irrigating farmland. The device consisted of a hollow cylinder with a center shaft and a spiral fixed to the inner Wall of the cylinder and center shaft. As the assembly rotated, water was conveyed and lifted from one location to another.

Fig. 2: View or Anatomy of Screw Conveyor

A. Conveyor Screw

Compact, manufactured straight and accurate in helical, sectional, ribbon and special designs to meet your requirements.

B. Job-Rated Components

Selected to meet the performance required. Precisely worked to insure a longer lasting, truer running unit. Jig-Drilled Couplings: Assures easy shaft alignment and assembly. Available with "Redi-Change" clamping key for quick disassembly of conveyor screw. Tem-U-Lac Self-Locking Coupling Bolts: Guards against system damage and costly.
C. Hangers and Bearings
Various styles and bearing materials selected to meet your needs.

D. Trough Ends
Several bearing and seal styles are available to match your needs.

E. Troughs, Covers, Clamps and Shrouds
Ruggedly constructed standard "U" and other styles of troughs including tubular. Covers, clamps and shrouds available for all applications.

F. Nu-Weld® Flange
Continuously welded steel flange holds trough in alignment.

G. Discharge Spouts
All types available...located where you need them...with hand, electric, hydraulic or pneumatic powered gates.

Supporting Feet and Saddles
Align and fasten the trough to the floor or existing structure. (3)

Sizing parameters of screw conveyor

![Sizing parameters for screw conveyors](image)

Fig. 3: Sizing Parameters of Screw Conveyor

1.3 Basic Theory and Design
Screw conveyors are volumetric conveying devices. With each revolution of the screw, a fixed volume of material is discharged. The purpose of a screw conveyor is to transfer product from one point to the next. Screw conveyors are always control fed at the inlet by another conveyor or metering device. Rotary valves, screw feeders, belt conveyors, grinders, or even other screw conveyors typically are connected to the inlet of a screw conveyor. Screw feeders are similar to

Screw conveyors except that screw feeders are always flood loaded or 100-percent full in the inlet area. Screw feeders are designed to volumetrically meter material from a hopper, bin or silo at a controlled rate. Many screw feeders utilize adjustable speed drives to allow for varying the material flow rate. The flow rate or capacity of a screw conveyor is measured in cubic feet per hour.

There are certain parameters for sizing a screw conveyor. The capacity calculation takes into account the outside diameter of the screw, the outside diameter of the pipe, the pitch of the screw and the trough loading. The calculation determines the capacity in cubic feet per hour that will be conveyed with each revolution per minute of screw rotation. It is not necessary to memorize this calculation. Most CEMA approved screw conveyor manufacturers have the capacity calculation and the CEMA guidelines as part of their screw conveyor design software.

1.4 Industrial Applications
Screw conveyors are used in thousands of applications throughout most industries.

The major industries that utilize screw conveyors are:

- Food Processing,* Cement industries
- Petroleum Refining,* Stone, Glass and Concrete
- Wastewater Treatment, * Rice and agriculture
- Chemicals,* Rubber and Plastics

Within each of these major industries are more specific applications for screw conveyors. For example, the production of portland cement is classified as part of the stone, glass and concrete industry. The production of limestone is also found under the same industry.

Each major industry can have as many as 20 more specific industries that use screw conveyors in their processes. Another example is the use of screw conveyors in the meat and poultry processing industries. These two industries are part of the major industry of food processing. Screw conveyors are used throughout the meat and poultry processing industries for conveying the byproducts or rendered products.

II. LITERATURE SURVEY

A. Article
Principle and Structure Analyses of Screw Conveyor
By: hxjqchina
Read more:
Screw conveyors and say ground dragon, apply to particle or powder material level conveying. Flotation cell tilting the conveying, vertical transportation and other forms. Single toggle jaw crusher Transportation distance model according to different and different, generally from 2 m to 70 m.

Screw conveying principle: rotating spiral leaf will material goes on for conveying screw conveyor. Limestone dryer Don't make the material with screw conveyor blades rotating force is the material with its weight and screw conveyor chassis to material friction resistance.

The spiral structure features: screw conveyor on the axis of the welding have spiral leaf, the face of the leaves conveying material according to different type of a solid surface type, belt type, China jaw crusher leaf surface face type, type. China mobile crusher Screw conveyor spiral axis direction of motion in the material terminal thrust bearing with material to the spiral in axial reaction force, the captain in a long, should add middle hangs bearing. Flotation cell The double helix conveyor is there are two respectively have the rotating blades welding about the screw conveyor.

Note: screw conveyor rotary axes to spin, decide the material transport direction, general screw conveyor in the design are in a single direction conveying design rotating blade.

B. Article2

Conveyors are equipment that is used for moving material from one position to another position. Belt conveyor is driven by electric motors and other moving parts. We can find belt conveyor in factories, warehouses and public transportation centers. It helps us to moving boxes and bulk quantity material handling. Before the advent of modern automation techniques, factory workers often have to travel from project to project, but due to belt conveyor it is easy to move, it saves workers time, stress, physical efforts and it allows project to come to the worker, instead of the worker to project.

These elevate belts are used to transport the loose material as well as loading and unloading in truck. You can find this technology in moving walks or escalators and many manufacturing units. There are many types of conveyor machines available in market such as Roller conveyors: these roller conveyors are available in both belt and chain driven model. Portable conveyors: these conveyors are movable it can be adjusted according to the product and its need.

Screw Conveyor is kind of conveyor with the help of The Screw Conveyors the rough or liquid materials rotate within the tube. Portable booster belt conveyor: It is self motorized host device; the adjustment of lever control does not need any efforts it locked automatically with the help of hydraulic/power screw.

These portable booster belt conveyors are most often used in loading or unloading wagon and truck. It can be operated easily it is a powerful in construction machine we can find Portable booster near construction site for loading or unloading of heavy material.

Magnetic separators is kind of conveyor used to remove metal trash and fines from dry or wet processing lines; it is used in separators of the beverage, bulk solids, cosmetics, dairy, food, or pharmaceutical industries. There is one design of screen which is called vibrating screen is used to keep out all welding on the sheet. The only difference in these conveyors is; their principle of operation and how they perform.

III. Methodology

The following methodology is adopted for the present work.

- Present work initially started from BEVCON VEYORS INDIA.PVT.LTD ‘Screw conveyor’ Component details. The component detail is studied and prepared 3-D model in UNI-GRAphics software.
- The component is studied for the operation required to convey the limestone powder used in cement industries, Design the component in the required shape and dimensions and analysed.
- Design calculations are carried for the component screw conveyor with the help of material properties which are specified by the company.
- Analysis work is carried by importing 3-D model into Ansys software. A FEM model of Shaft, Hollow shaft and side shafts are created by using Ansys processor. The material properties loads and boundary conditions are also specified in the Ansys Processor.
- Analysis work is done by applying loads on the Hollow shaft with side shafts and shaft then the results such as Displacement and Von-Mises stresses obtained.
- The results are compared with material properties of the material used for the component. Then we find that results obtained by using FEM are within the material properties. There we find that the component can withstand for given loads during operation.

IV. Selection of a Screw Conveyor

Primary considerations for the selection of a Screw Conveyor are:

1. Type and condition of the material to be handled, including maximum particle size, and, if available, the specific bulk density of the material to be conveyed.
2. Quantity of transported material, expressed in pounds or tons per hour.
3. The distance for which the material is to be conveyed.

In the next sections is the necessary information for the selection of a screw conveyor system, presented in a series of five steps. These steps are arranged in logical order, and are divided into separate sections for simplicity.

The five steps are:

1. Establishing the characteristics of the material to be conveyed.
2. Locating conveyor capacity (conveyor size and speed) on capacity tables.
3. Selection of conveyor components.
4. Calculation of required horsepower.
5. Checking of component torque capacities (including selection of shaft types and sizes).

All necessary calculations are expressed in graphic and equation form, and use of all charts, graphs, etc. will be explained fully at the end of each section.

Engineering data regarding the design of screw feeders and their selection is presented in a separate section, immediately following the screw conveyor data.

4.1 Inclined Screw Conveyors

Screw Conveyors can be operated with the flow of material inclined upward. When space allows, this is a very economical method of elevating and conveying. It is important to understand, however, that as the angle of inclination increases, the allowable capacity of a given unit rapidly decreases.

A standard Screw Conveyor inclined 15° upward will carry 75% of its rated horizontal capacity. At an inclination of 25°, a standard conveyor may only handle 50% of its horizontal capacity. These are estimated figures and will vary with the characteristic of the material being handled. Inclined Screw Conveyor capacities can be increased over short distances, if no intermediate hangers are required. Other aids in conveying on an incline are the use of shorter than standard pitch and/or tubular housings or shrouded conveyor trough covers. Very often it becomes necessary to use high speed to overcome the tendency of material to fall back.

Additional power is needed to convey on an incline. This added power is a function of the power required to lift the material. Judgment and experience in the art of conveying are required. Table (1), (2) & (3)

4.2 Formulae

4.2.1 Determine Design Capacity

\[
\text{Capacity} = \frac{\pi/4 \times (d_s^2-d_p^2) \times p \times k \times 60}{1728}
\]

Capacity in tph, Capacity in cu.ft/hr
Bulkdensity in t/m³, Diameter of screw = D_s
Diameter of pipe = D_p, Percent factor = k
Pitch of the screw = Diameter of screw (P=D)

4.3 Determine Speed

For screw conveyors with screws having standard pitch helical flights the conveyor speed may be calculated by the formula:

\[
N = \frac{\text{Required capacity, cubic feet per hour}}{\text{Cubic feet per hour at 1 revolution per minute}}
\]

4.4 Horsepower Calculation (Graphic Method of Calculation)

The total horsepower (TSHP) required at the drive shaft to drive the loaded conveyor system may be calculated graphically by use of the nomographs at the end of this section. The friction horsepower (FHP), determined with the first nomograph, added to the Material Horsepower (MHP), determined with the second nomograph, equals the Total Shaft Horsepower (TSHP). Friction Horsepower - A straight edge placed at the first two known values, conveyor size (related to hanger bearing class as listed in hanger bearing factor table) and length, will intersect a reference point on the centerline. A straight edge placed from this reference point to the third known value, conveyor speed, will intersect the unknown value, Friction Horsepower, on the last line.

Material Horsepower - A straight edge placed at the first two known values, conveyor capacity and Material Horsepower Factor, will intersect a reference point on the centerline.

4.5 Calculation by Equation

TSHP may also be calculated by equation using the following formulas:

1) Friction H.P. Calculation

Note: If calculated Material Horsepower is less than 5 it should be corrected for potential overload. The corrected horsepower value corresponding to the calculated Material Horsepower will be found on the lower scale of the Material Horsepower Overload Correction Chart.

Total Shaft H.P. Calculation

\[
\text{TSHP} = \text{FHP} + \text{MHP} \times \text{Corrected if below 5 HP.}
\]

Note: The actual motor horsepower required to drive the loaded conveyor system is dependent on the method used to reduce the speed the motor to the required speed of the conveyor. Drive losses must be

Taken into Consideration when selecting the motor and drive equipment.

Factor table (5) & (6);
4.6 Screw Conveyor Deflection

When using conveyor screws of standard length, deflection is seldom a problem. However, if longer than standard sections of screw are to be used, without intermediate hanger bearings, care should be taken to prevent the screw flights from contacting the trough because of excessive deflection. The deflection at mid span may be calculated from the following formula.

\[
D = \frac{5WL^3}{384 (29,000,000) (I)}
\]

Where:
- \(D\) = Deflection at mid span in inches
- \(W\) = Total screw weight in kgs
- \(L\) = Screw length in feet
- \(I\) = Movement of inertia of pipe or shaft

Table 5: Schedule 40 pipe, Schedule 80 pipe

V. Application Data

Table 4

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight lbs. per cu. ft.</th>
<th>Materiale code</th>
<th>Intermediate Bearing Selection</th>
<th>Component Series</th>
<th>MatI FacGo</th>
<th>Trough Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime stone powder</td>
<td>55-95</td>
<td>A46MY</td>
<td>H</td>
<td>2</td>
<td>1.6-2.2</td>
<td>30B</td>
</tr>
</tbody>
</table>

5.1 Input Parameters

1. Type of material to be conveyed: LIME STONE (DUST)
2. Bulk density of material given : 1.6 t/m³
3. Capacity required, in cu.ft./hr: 60 TPH or 1323.28 cu.ft/hr
4. Capacity required, in lbs. /hr : 132475 lbs/hr
5. Distance material to be conveyed : 4.0 M (15f)
6. Speed of the screw : 65rpm
7. Quantity of screw conveyors : 3
8. Diameter of screw Ds : 12"
9. Diameter of pipe DP : 3"
10. Pitch of the screw : Diameter of screw (P=D)
11. Percent factor k : 30%
12. L = Total length of conveyor, feet : 15f
13. N=Operating speed, RPM (per min):65rpm
14. Fd = Conveyor diameter factor : 55.0

5.2.2 Classify the Material

A46MY, Where,
- A- Very fine, 4- Flow ability (Sluggish)
- 6- Abrasiveness (Moderately Abrasive)
- M- Aerates and Becomes a Fluid
- Y- Very Light and Fluffy — May Be Windswept.

5.2.3 Determine Design Capacity, Capacity in tph = 60ph

\[
\text{Capacity} = \frac{\Pi/4*(d_s^2-d_p^2)*p*k*60}{1728}
\]

According to data given in table

- Diameter of screw \(D_s = 12\"
- Diameter of pipe \(D_p = 3\"
- Pitch of the screw = Diameter of screw \(P=D\)
- Percent factor k = 30%

\[
\text{Capacity} = \frac{3.14/4*(12^2-3^2)*12*30*60}{1728}
\]

For values of HPf + HPm greater than 5.2, Fo is 1.0

Trace the value of (HPf + HPm) vertically to the diagonal line, then across to the left where the Fo value is listed.
Hence from above graph the value of \( f \) is 1.19

\[
HP_F = \frac{L*N*FD*f}{1,000,000}
\]
\[
= \frac{15*65*55.0*1}{1,000,000} = 0.0536 \text{ horse power}
\]

\[
C*L*W* F^2* Fm*Fp \quad \text{(Horsepower to run the material)}
\]
\[
HP_m = \frac{1000000}{1325.36*15*95*1*2*1}
\]
\[
= 3.777 \text{ horse power}
\]

Total HP = (HPF + HPm) * FO
\[
= (0.0536 + 3.777) * 1.19 \text{ from graph}
\]
\[
= 4.797 \text{ horse power}
\]

Since 4.797 horse power motor is not available taking motor horse power as 5 HP

Total HP = 5 horse power

SOL: - 4.797 Horsepower is required to convey 1325.36 CFH Lime stone powder, spent wet in a 12 conveyor for 15 feet. A 5 H.P. motor should be used.

5.3 Screw Conveyor Deflection

When using conveyor screws of standard length, deflection is seldom a problem. However, if longer than standard sections of screw are to be used, without intermediate hanger bearings, care should be taken to prevent the screw flights from contacting the trough because of excessive deflection. The deflection at mid span may be calculated from the following formula.

\[
D = \frac{5WL^3}{384 (29,000,000) (l)}
\]

Where: \( D \) = Deflection at mid span in inches

\( W \) = Total screw weight in kgs = 1000kg = 2204.62 lbs

\( L \) = Screw length in feet = 4mts = 15 ft = 158 inch

\( l \) = Movement of inertia of pipe or shaft, see table 6 or 7 = 3.02

\[
D = \frac{5*2204.62*158^3}{384*29,000,000*3.02}
\]
\[
= 1.29 \text{ inch (or) 32.766 mm}
\]

6.5 General Operation

Start with a Sketch,

Use the Sketcher to freehand a sketch, and dimension an "outline" of Curves. You can then sweep the sketch using Extruded Body or Revolved Body to create a solid or sheet body. Editing a dimension of the sketch not only modifies the geometry of the sketch, but also the body created from the sketch.

Creating and Editing Features

Within Modeling, you can position a feature relative to the geometry on your model using Positioning Methods, where you position dimension.

You can create reference features, such as Datum Planes, retains that association during edits to the model. You can use a datum plane as a reference plane in constructing sketches, creating features, and positioning.

6.6 Analytical drawings of shaft

\[\text{Fig (4) component screw, Fig (5) component hangers}\]

\[\text{Fig (6) component shaft, Fig (7) conveyor shroud}\]

\[\text{Fig (8) Von misses stress on shaft, Fig (9) Displacement position}\]

\[\text{Fig (10) Zoomed view of shaft}\]
6.7 Analytical drawings of shaft

ANSYS images for solid shaft case

VI. RESULTS AND DISCUSSIONS

Stress

Stresses on the Hollow shaft is show in the below image which is obtained from Ansys.

Displacement

The displacement in the Hollow shaft due to load applying is show in the image which is obtained from Ansys.

Stress

Stresses on the Solid shaft is show in the below image which is obtained from Ansys.

Displacement

The displacement in the Solid shaft due to load applying is show in the image which is obtained from Ansys.

The above fig is showing vonmises stress value. Vonmises stress depends on vonmises theory of failure.

The above fig is showing distributed shape or variation of geometry shape after applying loads. The maximum displacement is 0.000000259 mm occurring at the centre of the shaft.

VII. CONCLUSION

Until recently the primary analysis method had been hand calculations and empirical curves. New computer advances have made finite element analysis (FEA) a practical tool in study of Shaft, especially in determining stresses. In this paper we have used Ansys software to do the analysis on the Shaft. This tasks performed in this project are follows

Design calculations done by the as per specifications.

According to design calculations develop the modeling by using UNI-GRAPHICS software.

Done by the analysis by using ANSYS package.

According to ANSYS results the following results are found

Hollow shaft is having 33% less weight when compared to solid shaft

The stress and displacement values for hollow shaft assembly are little bit higher than solid shaft but the values are within the minimum strength of the material.

So it is better to use Hollow shaft assembly instead of solid shaft. By this we can reduce the cost by reducing material quantity and can increase the mechanical efficiency by reducing weight.

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