Design of continuous loading vertical chain conveyor

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ABSTRACT

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. The main purpose of this project is to safely lift the load at the rate of 6m/min. This paper consists of, selection, the design of basic mechanical elements. This system is able to overcome the drawbacks of inclined belt conveyor, achieves desired height and occupies less floor space as the material is transformed in vertically upward direction. This Chain Conveyor utilizes a continuous chain arrangement, carrying a series of the single pallet for lifting the load. The chain arrangement is driven by a motor, and the material suspended on the pallets is conveyed to the next floor.

Keywords— Roller chain, Sprockets, Roller chain flexible coupling, Pedestal bearing

1. MATERIAL HANDLING

Material handling involves short-distance movement within the confines of a building or between a building and a transportation vehicle. It uses a wide range of manual, semi-automated, and automated equipment and includes consideration of the protection, storage, and control of materials throughout their manufacturing, warehousing, distribution, consumption, and disposal. Material handling can be used to create time and place utility through the handling, storage, and control of material, as distinct from manufacturing, which creates form utility by changing the shape, form, and makeup of the material.

1.1 Types of material handling

1.1.1 Manual Handling: Manual handling refers to the use of a worker’s hands to move individual containers by lifting, lowering, and filling, emptying, or carrying them. It can expose workers to physical conditions that can lead to injuries that represent a large percentage of the over half a million cases of musculoskeletal disorders reported in each year, and often involve strains and sprains to the lower back, shoulders, and upper limbs. Ergonomic improvements can be used to modify manual handling tasks to reduce injury.

1.1.2 Automated handling: Whenever technically and economically feasible, equipment can be used to reduce and sometimes replace the need to manually handle material. Most existing material handling equipment is only semi-automated because a human operator is needed for tasks like loading/unloading and driving that are difficult and/or too costly to fully automate, although ongoing advances in sensing, machine intelligence, and robotics have made it possible to fully automate an increasing number of handling tasks.

2. CONVEYOR SYSTEM

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. 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. Many kinds of conveying
systems are available and are used according to the various needs of different 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.

3. CHAIN CONVEYOR
A chain conveyor is a type of conveyor system for moving material through production lines. Chain conveyors utilize a powered continuous chain arrangement, carrying a series of single pendants. The chain arrangement is driven by a motor, and the material suspended on the pendants is conveyed.

Chain conveyors are used for moving products down an assembly line and/or around a manufacturing or warehousing facility. Chain conveyors are primarily used to transport heavy unit loads, e.g. pallets, grid boxes, and industrial containers. These conveyors can be single or double chain strand in configuration. The load is positioned on the chains; the friction pulls the load forward. Chain conveyors are generally easy to install and have very minimum maintenance for users.

4. DESIGN

4.1 Design considerations
- Speed of conveyor = 6m/min
- Material weight to be lifted = 20kg

Two pallets with one carrying material to be handled at any instant
- \( M = \) Material weight = 20kg
- \( C = \) Additional weight which includes attachment, crossbars, fixings = 20kg

4.2 Selection of chain
Chain pull:
\[
P = \frac{9.81 \times (C + M) \times S \times F}{\text{Number Of Chains}}
\]
\[
= \frac{9.81 \times 40 \times 1.2 \times 1 \times 1}{4}
\]
\[
= 117.2 \text{ N}
\]

Thus from standard catalogue of chains, chain number 40 with a maximum allowable load of 4.17 KN is selected.

Specifications:
- Pitch = 12.7 mm
- Roller Diameter = 7.92 mm
- Inner Width = 7.95 mm

Pin Dimensions:
- Diameter = 3.96 mm
- Length = 17.9 mm
- Link Plate
- Height = 8.8 mm
- Thickness = 1.5 mm

4.3 Selection of Sprocket
Assuming no. of teeth as 19
Thus from standard catalogue of SKF sprocket,
No of teeth = 19
Pitch diameter = 77.16 mm

Material—En8—carbon steel
According to B.S 970 chemical composition of En8
Carbon \( \rightarrow \) 0.36 to 0.44
Manganese \( \rightarrow \) 0.6 to 1
Phosphorous \( \rightarrow \) 0.05
Sulphur \( \rightarrow \) 0.005

4.4 Selection of bearing
Radial load = 400N
Shaft Diameter = 25 mm

\[ K_a = 1.5 \]
Dynamic capacity = 14KN
\[
L_{h10} = 10000
\]

Rating life of bearing
\[
L_{10} = \frac{L_{h10} \times 60 \times N}{10^6}
\]
\[
= \frac{10000 \times 60 \times 32}{10^6}
\]
\[
L_{10} = 15 \text{ Million Revolutions}
\]

\[
P_e = F_b \times K_a
\]
\[
= 400 \times 1.5
\]
\[
= 600 \text{ N}
\]
\[
L_{10} = \left( \frac{C}{P_e} \right)^3
\]
\[
14 = \left( \frac{C}{600} \right)^3
\]
\[
C = 1446.08 \text{ N} > 7.8 \text{ KN}
\]

This design is safe and selecting bearing number UCP205 with 25 mm diameter.

Table 1: Selection of chain

Table 2: Bearing Specifications

4.5 Design of key
Material: Mild Steel
\[
\tau_s = 56.25 \text{ N/mm}^2
\]
Selecting square key, Hence
\[
h = w = \frac{d}{4} = \frac{25}{4} = 6.25 \text{ mm}
\]
Selecting next standard value = 8 mm
Considering crushing of key

\[ \sigma_c = \frac{4T}{dh \ell} \]
\[ l = \frac{25 \times 6.25 \times 112.5}{24.576} \approx 30 \text{ mm} \]

Considering sharing of key

\[ \tau_s = \frac{2T}{dh \ell} \]
\[ l = \frac{25 \times 6.25 \times 56.25}{24.57} \approx 30 \text{ mm} \]

Key Dimensions \( h = w = 8 \text{ mm} \)
\( l = 30 \text{ mm} \)

### Table 3: Selection of key

**Keyway and Key Size Dimensions**

<table>
<thead>
<tr>
<th>Material Selection (English Dimensions):</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Keyway</td>
<td>Keyway</td>
<td>Keyway</td>
<td>Keyway</td>
</tr>
<tr>
<td>Width (W)</td>
<td>Depth (D)</td>
<td>Width (W)</td>
<td>Depth (D)</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

### 4.6 Design of coupling

**Service factor:**
Selecting service factor of 1.5 for an electric motor with uneven load-4hrs/day used for service classification number B for conveyors Multiply horsepower of driver unit by the service factor

Design horsepower = motor horsepower \( \times \) service factor
\[ = 0.373 \times 1.5 \]
\[ = 0.5595 \]

Max RPM = 32 RPM
Power = 1/2 HP

Hence selecting coupling number-NT 8316 with a max bore diameter of 32mm and max design power of 2 KW.

### Table 4: Selection chain flexible coupling

<p>| Selection of the size of the couplings |
| --- | --- | --- | --- | --- | --- |</p>
<table>
<thead>
<tr>
<th>Series</th>
<th>Standard couplings</th>
<th>Direction of rotation</th>
<th>Electric use or machine tools</th>
<th>Torque capacity (Nm)</th>
<th>Horsepower (HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Universal joint, variable angle, universal mounting</td>
<td>Any way</td>
<td>30-150</td>
<td>0.3-2.5</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Universal joint, variable angle, flexible mounting</td>
<td>Any way</td>
<td>30-150</td>
<td>0.3-2.5</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Universal joint, variable angle, flexible mounting</td>
<td>Any way</td>
<td>30-150</td>
<td>0.3-2.5</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Universal joint, variable angle, flexible mounting</td>
<td>Any way</td>
<td>30-150</td>
<td>0.3-2.5</td>
<td></td>
</tr>
</tbody>
</table>

### 4.7 Design of shaft

**Material selection:**
Mild steel of the following composition is selected
Carbon-0.16 to 0.18 % (max allowable 0.25 %)
Manganese- 0.7 to 0.9 %
Sulphur-0.04 %
Phosphoros-0.04 %
UTS = 840 MPa
Yield stress = 247 MPa

### Fig. 3: Shaft loading diagram

- \( F_{TB} = 400 \text{ N} \)
- \( F_{TC} = 50 \text{ N} \)
- \( R_B = R_C = R_D = R_E = 38.58 \text{ mm} \)
- \( T_B = T_E = 15600 \text{ N-mm} \)
- \( T_C = T_D = 1950 \text{ N-mm} \)
- \( T_S = 0.75(0.18 \text{ S}_{ut}) = 113.4 \text{ N/mm}^2 \)
- \( T_S = 0.75(0.3 \text{ S}_{yt}) = 56.25 \text{ N/mm}^2 \)
- \( R_F \times 675 = 400 \times 509.1 + 50 \times 412.5 + 50 \times 262.5 + 400 \times 165.9 = 450.22 \text{ N} \)
- \( R_A = 450.22 \text{ N} \)
- \( B_{MB} = 74691.498 \text{ N-mm} \)
- \( B_{MC} = 450.22 \times 262.5 - 400 \times 96.6 = 79542.75 \text{ N-mm} \)
- \( B_{MD} = 450.22 \times 412.5 - 400 \times 246.6 - 50 \times 150 = 79575.75 \text{ N-mm} \)
- \( B_{ME} = 450.22 \times 509.1 - 400 \times 343.2 - 50 \times 246.6 = 79597.002 \text{ N-mm} \)
\[ T_e = \sqrt{(1 \times 79597)^2 + (1.5 \times 15600)^2} = 82965.30847 \text{ N-mm} \]

\[ \tau_{\max} = \frac{16T_e}{\pi d^3} \]

\[ 56.25 = \frac{16 \times 82965.30487}{\pi d^3} \]

\[ d = 19.5845 \text{ mm} \]

\[ V = r \omega \]

\[ 6000 = 39 \times 2\pi N \]

\[ N=31,4853 \text{ rpm} \approx 32 \text{ rpm} \]

\[ P=283 \text{ W} \]

\[ P= \frac{2\pi NT}{60} \]

\[ 0.283 = \frac{2\pi (32) T}{60 \times 10^3} \]

\[ T = 108.0698 \text{ Nm} \]

\[ \frac{T}{J} = \frac{\tau}{R} \]

\[ \frac{108.098 \times 10^3}{\frac{\pi}{32} \times (19.5845)^4} = \frac{\tau}{12.50} \]

\[ \tau = 73.2909 \text{ N/mm}^2 > 56.25 \]

Hence, design is not safe.

Selecting shaft diameter as 25 mm

\[ \tau = \frac{108.098 \times 10^3}{\frac{\pi}{32} \times (25)^4} = \frac{\tau}{12.50} \]

\[ \tau = 35.23 \text{ N/mm}^2 \]

Hence design is Safe.

### 4.8 Selection of geared motor

Power transmitted by the chain can be expressed by equation

\[ K_w = \frac{P \times V}{1000} \]

Where \( P= \) allowable tension \( = 120 \times 10 = 1200 \text{ N} \)

\[ V=6 \text{ m/min} = 6/60 = 0.1 \text{ m/sec} \]

\[ K_w = \frac{1200 \times 0.1}{1000} = 0.12 \]

\( K_s \) considering service factor as 1 for uniform driven load with an electric motor

\( K_1 = \) tooth correction factor as 0.53 for 19 number of teeth

\( K_2 = \) Multiple Strand Factor as 1 for 1 strand

\[ \text{KW rating of chain} = \frac{K_w \times K_s}{K_1 \times K_2} \]

\[ = \frac{0.12 \times 1}{0.53} = 0.2264 \text{ KW} \]

Selecting service factor as 1.1 for electric motor working 8 hrs per day with moderate shock

Output rpm is 32 rpm

Hence according to output rpm and service factor, we select motor of 0.5 Hp [E-37-71-4 (30 kg)]

Thus, Standard geared motor with following Specifications is selected 3 Phase, AC, 0.5 HP (0.3728 KW) geared motor with output speed 32 rpm

Mounting→ Foot Mounted

### 4.9 Specifications

<table>
<thead>
<tr>
<th>Parts</th>
<th>Material</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>Mild Steel</td>
<td>Square Tube (50mm x 50mm x 2mm)</td>
</tr>
<tr>
<td>Shaft</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sprocket</td>
<td>En8 (Carbon Steel)</td>
<td>19 Teeth, ½ Inch Pitch</td>
</tr>
<tr>
<td>Roller Chain</td>
<td>Stainless Steel</td>
<td>½ Inch Pitch</td>
</tr>
<tr>
<td>Bearing</td>
<td>Standard</td>
<td>ID = 25mm</td>
</tr>
<tr>
<td>Geared Motor</td>
<td>-</td>
<td>½ HP, 3 Phase, Foot Mounted, Output Speed = 32 RPM</td>
</tr>
<tr>
<td>Roller chain flexible</td>
<td>En8 (Carbon steel)</td>
<td>NT 8316</td>
</tr>
</tbody>
</table>
5. CONCLUSION
Thus we can conclude that the designed Chain Conveyor is able to safely transport materials from one floor to another floor, which when done by human labour would be strenuous and expensive.

The designed Chain Conveyor is able to occupy less space and this system is less complex as compared to Inclined Belt Conveyor.

6. FUTURE SCOPE
Rubber Blockchain can be used which has outstanding features, that it has no links, silent running, wear resistant and virtually maintenance free, all excellent qualities further enhanced by its corrosion-free design.

With advanced automation, no operator supervision will be required.

A number of pallets can be increased for increasing rate of material transport.

Sensors can be used such as proximity sensors to detect approaching goods and stop the in feed conveyor until the platforms are incorrect position.

7. REFERENCES