Experimental Analysis of Bucket Elevator Chain Breakdown

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Abstract: A Bucket Elevator is a material handling equipment. It can elevate variety of bulk material from light to heavy and from fine to large lumps. It consists of rubber belt and on which metallic and plastic bucket are fixed. In this study we are finding the various faults related to the sprocket and chain failure and diagnosis this fault using the various methods of the failure causes. The present work is aimed at designing and analysis required to decide the capacity of a chain drive that should be used to drive a bucket elevator of particular specification. In this study we minimize the break-down of bucket elevator by replacing simplex roller chain and sprocket by duplex roller chain. Duplex chain have more breaking load capacity than the Simplex chain. In duplex chain power rating and tension in chain are less than the simplex chain.

Keywords:Bucket Elevator, Simplex chain, Duplex chain.

1. INTRODUCTION

1.1 BUCKET ELEVATOR

1.1 Introduction: - A Bucket Elevator can elevate a variety of bulk material from light to heavy and from fine to large lumps. A Centrifugal discharge elevator may be vertical or inclined. Vertical elevator depends entirely on the action of centrifugal force to get the material into the discharge chute and must be run at speeds relatively high. It consists of:

1) Bucket to contain the material.
2) A belt to carry the bucket and transmit the pull
3) Means to drive the belt
4) Accessories for loading the buckets or picking up the material for receiving the discharged material for maintaining the belt tension and for enclosing and protecting the elevator.

The Bucket Elevator are used in:

a) Foundry (Casting) industries
b) Cement industries
c) Fertilizer industries
d) Paper mill
e) Powder industries
f) Coal mines
g) Pharmaceutical industries

1.2 Part of Bucket Elevator:-

I) Casing - Elevator will consist of boot section, intermediate casing and head section. Elevator boot, intermediate casings and head casing will be of welded or bolted connection. Fabricated from rolled steel, Mild Steel, Angle section and sheets. The sheet thickness for the intermediate casings and head casing will be 3mm whereas for the boot section and the receiving chute sheet thickness will be 5mm. The intermediate casing will not exceed 1.8 to 2.5m. Boot section will be provided with inspection door on both side for cleaning and replacement of buckets.

II) Head section: It will be provided with a crowned head pulley of Mild steel of Mild steel plate welded construction. The pulley face will be straight approximately for 1/3 rd. face length in the center. For the balance portion both side straight length, the pulley have crown.

III) Boot section: It will be provided with bottom pulley of MS construction mounted in externally lubricated pillow block bearing.
IV) Take up device: It is provided at bottom section or top section elevator for elongation of belt

V) Drive unit: Elevator will be head driven. The drive motor will be totally enclosed fan cooled squirrel cage induction motor suitable for operation 3 phase 3.7 kW AC supply system at 1440 rpm.

VI) Belt: The belt will be Nylon fabric 350mm, 5 ply Grade M-24 or heat resisting quality with 3mm bottom.

![Belt with Buckets](image)

**Fig. No-1.3** Belt with Buckets

### 1.6 Chain drive

A Chain drive consists of an endless chain wrapped around two sprockets. A Chain can be defined as a series of link connected by pin joints. The Sprocket is a toothed wheel with a special profile for the teeth. The chain drive is intermediate between belt and gear drives.

1.6.1 There are three types of chains:

a) Load lifting chains
b) Hauling chains
c) Power transmission chains

1.6.2 Load lifting chains are used for suspending raising or lowering loads in materials handling equipment. The popular example of this chain is a link. Link chain are used in low capacity hoists, winches and hand operated cranes.

1.6.3 Hauling chains are used for carrying materials continuously by sliding, pulling or carrying in conveyors. The example of this is a Block chain. It consist of sideplates of simple shapes and pins.

1.6.4 Power transmission chains are used for transmitting power from one's haft to another.

### 1.7 Roller Chain:

A Roller chain consists of following five parts:

a) Pin
b) Bushing
c) Roller
d) Inner link plate
e) Outer link plate

The pin is press fitted to two outer link plates, while the bush is press fitted to inner link plates. The pin form a swivel joint and the outer link is free to swivel with respect to the inner link. The roller are freely fitted on bush and during engagement turn with the teeth of the sprocket wheels. This results in rolling friction instead of sliding friction between roller and sprocket teeth. The rolling friction reduces wear and frictional power loss and improves the efficiency of the chain drive.

The inner and outer link plates are made of medium carbon steels. These link plates are blanked from cold rolled sheets and hardened to 50 HRC. The pins, bushes and roller are made of case carburizing alloy steels and hardened to 50 HRC. The pitch (p) of the chain is the linear distance between the axes of adjacent rollers. Roller chain are standardized and manufactured on the basis of the pitch.

These chains are available in single strand or multi strand constructions such as simple, duplex or triplex chains.

![Figure No.1.7 Duplex Roller Chain](image)

**Figure No.1.7** Duplex Roller Chain

### 1.8 Sprocket Wheels:

1.8.1 Duplex Sprocket: There are different construction for sprocket wheel as shown in fig. Small sprockets up to 100 mm in diameter are usually made of a disk or a solid disk with a hub on one side. They are machined from low carbon steel bars. Large sprocket with more than 100 mm diameter are either welded to a steel hub or bolted to a cast iron hub. In general sprocket are made of low carbon or medium carbon steels. In certain application stainless steel is used for sprockets. When the chain velocity is less used for sprockets. When the chain velocity is less than 180 m/min, the teeth of the
sprocketwheel are heat treated to obtain a hardness of 180BHN. For high steel speed application thererecommended surface hardness is 300 to 500 BHN. The teeth are hardened either by carburizing in case of low Carbon steel or by quenching and tempering in case of high carbon steel.

1.8.2 Identification of Faults:

a) Wear of Sprocket  
b) Noise in the drive.

c) Vibration in the sprocket  
d) Excessive chain tension.

e) Jerk due to the belt  
f) Misalignment of the chain and sprocket.

1.9 Problem Area for the Project:

The Company is facing the problem of the breakdown of Bucket Elevator. They have to keep bucket elevator working continuously to achieve mass production. The failure of working of bucket elevator causes loss of production which create impact on the customer commitment and quality.

2.0 Objective:

1) To study the existing layout and working of company.

2) To eliminate chain drive breakdown of elevator by introducing new arrangement.

3) To reduce the breakdown time.

2.1 Design of Simplex chain & Duplex chain

2.1.1 Given data:

Power of driving sprocket = 3.7 KW
Speed of Driving sprocket = 1440 rpm.
Multistrand factor (K1) = 1 (For simplex Chain)
Tooth correction factor (K2) = 1
Service factor (Ks) = 1.3

2.1.2 KW rating of the chain

\[ PowerP = \frac{6.98 - 5.28}{1800 - 1400} \times (1440 - 1400) \]
\[ P = 5.45 \text{ KW} \]

From Table Chain 08A is suitable for the application.

2.1.1.3. Number of Links:

We know that Pitch (p) = 12.7 mm \( d_1 = 2.51 \text{ mm} \) \( b_1 = 7.75 \text{ mm} \)

\[ \frac{N_2}{N_1} = \frac{Z_1}{Z_2} \]

\[ N_2 = \frac{17}{24} \times 1440 = 1024 \text{ rpm} \]

The center distance between the ages of the driving and driven sprocket should be between 30 to 50 times of pitch of the chain.

2.1.1.4. Centre distance \((a)\) =

\[ = 2X \left\{ \frac{a}{p} + \frac{(Z_1 + Z_2)}{2} - \frac{p}{a} \times \left( \frac{Z_2 - Z_1}{2\pi} \right)^2 \right\} \]

\[ = 2 \times \frac{635}{12.7} + \frac{(17 + 24)}{2} - \frac{12.7}{635} + \frac{(24 - 17)^2}{2\pi} \]

\[ = 121.76 = 122 \text{ links} \]

2.1.1.5. Correct center distance

\[ = \frac{p}{4} \left\{ L_n - \frac{z_2 + z_1}{2} \right\} + \frac{2}{8} \left( L_n - \frac{z_1 + z_2}{2} \right)^2 - 8 \left( \frac{z_2 - z_1}{2\pi} \right)^2 \]

\[ = 12.7 \times 102 + \frac{2}{8} \times \left( 102^2 - 8 \times \frac{(24 - 17)^2}{2\pi} \right) \]

\[ = 646.52 \text{ mm} \]

Correct center distance \((a) = 646.52 \text{ mm} \)

The center distance calculated by the formula does not provide any sag. In practice a small amount of sag is essential for the link to take the best position on the sprocket wheel.

The center distance is therefore reduced by a margin of 0.002a to 0.004a to account for the sag.

2.1.1.6. Distance for sag = 0.002a to 0.004a

\[ = 0.002 \times 646.52 \text{ to } 0.004 \times 646.52 \]

\[ = 1.3 \text{ mm to } 2.58 \text{ mm} \]

2.1.1.7. Length of the chain \(L = \text{ Number of link X pitch} \)

\[ = 122 \times 12.7 \]
2.1.1.8. Pitch Circle Diameter of drivingsprocket:

\[ D_1 = p \times \text{Cosec} \left( \frac{180}{Z_1} \right) \]

For the driven sprocket:

\[ D_2 = \frac{Z_2 \times N_1}{N_2} \]

\[ = 17 \times \frac{1440}{1020} = 1020 \text{ rpm} \]

2.1.1.9. Pitch circle diameter of driven sprocket (D2):

\[ D_2 = 12.7 \times \text{Cosec} \left( \frac{180}{24} \right) \]

\[ = 97.30 \text{ mm} \]

\[ = 0.09730 \text{ m} \]

2.1.2.0. Pitch line velocity of driving sprocket:

\[ v = \frac{Z_1 \times p \times N_1}{60000} \]

\[ = \frac{17 \times 12.7 \times 1440}{60000} = 5.18 \text{ m/s} \]

2.1.2.1. Tension in the chain (P1):

\[ P_1 = \frac{1000 \times \text{Power rating of motor}}{v} \]

\[ = \frac{1000 \times 3.7}{5.18} = 714.285 \text{ N} \]

2.1.2.2. Factor of safety:

\[ = \frac{\text{Breaking load}}{\text{Chain tension}} \]

\[ = \frac{13800}{714.285} = 19.32 \]

2.1.2.3. Dimension of the driving sprocket wheel:

Pitch p = 12.7mm, d1 = 8.51 mm, b1 = 7.75 mm

a) Outer diameter:

1) \( (D_a)_{\text{max}} = D + 1.25p - d_1 \)

\[ = 69.11 + 1.25(12.7) - 8.5 \]

\[ = 76.475 \text{ mm} \]

2) \( (D_a)_{\text{min}} = D + p(1 - \frac{1.6}{17}) - d_1 \)

\[ = 69.11 + 12.7(1 - \frac{1.6}{17}) - 8.51 \]

\[ = 72.1 \text{ mm} \]

b) Root diameter and roller seating radius:

\[ (r_1)_{\text{max}} = 0.505d_1 + 0.069\sqrt{d_1} \]

\[ = 0.505 \times 8.51 + 0.069(\sqrt{8.51}) \]

\[ = 4.437 \text{ mm} \]

\[ (r_1)_{\text{min}} = 0.505d_1 \]

\[ = 0.505 \times 8.51 = 4.297 \text{ mm} \]

C) Root diameter (Df):

\[ D_f = D - 2r_1 \]

\[ = 69.11 - (2 \times 4.29) = 60.53 \text{ mm} \]

3.1. Design of Duplex chain

*We know the power = 3.7 kW, speed N1 = 1440 rpm*

Number on of teeth on driving sprocket = Z1 = 17

Multistrand factor K1 = 1.7 (From Table 4.6)

Tooth correction factor K2 = 1.00

Service factor Ks = 1.3

1) \[ K \times \text{KW rating of chain} = \frac{\text{Power to be transmitted by motor}}{K_1 \times K_2} \times \]

\[ = \frac{3.7 \times 1.3}{1.7 \times 1} = 2.82 \text{ kW} \]

By using interpolation method we find the value of power rating at 1440 rpm,

\[ P = 2.73 + \frac{(3.44-2.73)}{1800-1400} \times (1440-1400) \]

\[ = 2.80 \text{ kW} \]

Referring to table the power rating of the chain 06 B is 2.73 kw and 3.44 kw at 1400 rpm and 1800 rpm respectively. Therefore the chain number 06B is selected.

The duplex chain 06 B is selected which have less pitch than present simplex chain (12.7mm)

So we select duplex chain of 10A from Table 4.5 with pitch of 15.875 mm.

The dimension of Chain 10A are pitch = 15.875 mm, d1 = 10.16 mm, b1 = 9.4 mm, p1 = 18.11 mm and breaking load 43600 N.

3.2 For the driving sprocket Pitch Circle Diameter:

\[ D_1 = p \times \text{Cosec} \left( \frac{180}{17} \right) \]

\[ = 15.875 \times \text{Cosec} \left( \frac{180}{17} \right) \]

\[ = 86.465 \text{ mm} \]

For the driven Sprocket:

\[ N_2 = \left( \frac{Z_1}{N_1} \right) X \frac{1440}{24} \]
= 1020 rpm

3.3. Pitch circle diameter of driven sprocket \( D_2 = p \times \text{Cosec} \left( \frac{15.875}{7.5} \right) \) =121.62 mm

To make compact construction the center distance is taken as 30 p to 50 p

\[ a = 30 \times \text{pitch} = 30 \times 15.875 = 476.25 \text{ mm} \]

We know that \( Z_1 = 17, Z_2 = 24 \) \( N_1 = 1440 \text{ rpm}, p = 15.875 \text{ mm} \)

\[ \text{L}_n = 2\left( \frac{9}{p} + \frac{Z_1+Z_2}{2} \right) \times \frac{Z_2-Z_1}{2\pi} + \left( \frac{24-17}{2\pi} \right)^2 = 80.5 \]

\[ \text{L}_n = 80 \text{ links} \]

Correct center distance: For simplification

\[ \left[ \text{L}_n - \left( \frac{Z_1+Z_2}{2} \right) \right] = 59.5 \text{ mm} \]

3.4. So Correct Centre distance:

\[ = \frac{p}{4} \left[ \text{L}_n - \left( \frac{Z_1+Z_2}{2} \right) \right] + \sqrt{\left[ \text{L}_n - \left( \frac{Z_1+Z_2}{2} \right) \right] - 8 \left( \frac{Z_2-Z_1}{2\pi} \right)^2} \]

\[ = 471.86 \text{ mm} \]

3.5 Pitch line velocity = \( \frac{Z_1 \times p \times X_1}{60000} \)

\[ = \frac{17 	imes 15.875 \times 1440}{60000} = 6.47 \text{ m/s} \]

3.6. Tension in chain \( P_1 = \frac{1000 \times X \times 3.7}{6.47} \)

= 571.870 N

3.7. Factor of Safety:

\[ = \frac{\text{Breaking load}}{\text{Chain tension}} = \frac{43600}{571.87} = 76.24 \]

3.8. Dimension of the driving sprocket wheel:

i) Outer (Top) diameter

\[ (D_a)_\text{max} = D_1 + 1.25p - d_1 \]

\[ = 86.465 + 1.25 \times 15.875 - 10.16 \]

= 96.145 mm

Fig 3.1 Paper on Bucket Elevator Duplex chain Drive

Results:

**Difference between Simple chain and duplex on the basis of following point:**

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Point to be considered</th>
<th>Simplex chain</th>
<th>Duplex chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strength</td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td>2</td>
<td>Power rating</td>
<td>4.81 kw</td>
<td>2.85 kw</td>
</tr>
<tr>
<td>3</td>
<td>Length of chain</td>
<td>1549.4 mm</td>
<td>1524 mm</td>
</tr>
<tr>
<td>4</td>
<td>Pitch line velocity</td>
<td>5.18 m/s</td>
<td>6.47 m/s</td>
</tr>
<tr>
<td>5</td>
<td>Breaking load</td>
<td>13800 N</td>
<td>43600 N</td>
</tr>
<tr>
<td>6</td>
<td>Multi strand factor</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>7</td>
<td>Tension in chain</td>
<td>714.285 N</td>
<td>571.870 N</td>
</tr>
<tr>
<td>8</td>
<td>Number of link required</td>
<td>122</td>
<td>80</td>
</tr>
</tbody>
</table>
Conclusion

The chain drive should be horizontal. The driving side should be on the top. To avoid the breakdown Chain drive adequate tension in the chain is the most important requirement of chain drive. Chain life is reduced if the chain is too tight or to loose. Too tight a chain results in an unnecessary load in the chain and increased bearing reaction. From above Experimental Analysis we concluded that

1) Duplex chain has more strength than Simplex roller chain.

2) The Duplex chains have more breaking load value than simplex chain.

3) The power rating and tension in chain in duplex chain less than simplex chain.

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BIOGRAPHIES

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