Trials and Analysis on Belt Conveyor System used for Cooling of Casting Mould

S. P. Mane1, P. A. Mane2, C. G. Harage1 and R. R. Prajapati1
1PVPIT, Budhgaon, Sangli, Maharashtra, India.
2Walchand College of Engineering, Sangli-416415, Maharashtra, India.

ABSTRACT
Belt conveyor system is the transportation of material from one location to another location. Belt conveyor has high load carrying capacity (upto 30000 t/h), large length of conveying path (upto 3-4 km), simple design, easy maintenance and high reliability of operation. Belt conveyor system is also used in various industries such as the material transport in foundry shop like supply and distribution of moulding sand, moulds and removal of waste, coal and mining industry, sugar industry, agricultural industry, bagasse industry, fuel industry etc. In this paper the study is carried out on DISA pattern moulding machine to meet the requirement of higher weight castings. From the DISA specification the belt conveyor system is designed by using different standards like CEMA (Conveyor Equipment Manufacture’s Association) standards, some handbooks of belt conveyor system etc. then this parameter are verified by using Belt Comp software. The result got from the Belt Comp software is in close agreement of theoretical results. After the design the manufacturing is done and the installation is done on the manufacturer’s site. The trials are carried out on the belt conveyor system successfully and the problems occurs during the trials are overcome in the analysis by taking proper steps. The present discussion aims to Trial and Analysis on belt conveyor system.

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Belt Width = \( \frac{T_1}{\text{kg/inch}} \)

\( T_1 \) is calculated by taking different parameters such as live load, dead load, belt pull, deflectors, transition point etc.

As mould temperature is 180 degrees, heat resistant belt is required. Therefore pyroshield belt (KEP 800/4) is selected having the properties like high tensile strength, longer working life, robust construction, corrosion resistance, wear and tear resistance.

Belt Strength = 167.37 kg/inch

By substituting the values in above equation we get the belt width=1200mm.

Effective belt tension \( (T_e) \) =Total empty friction + Load friction + Load slope tension

Total empty friction= \( F_e = (L+t) \times W \times 9.81 \times 10^{-3} \) =14.13KN

Load Friction= \( F_l = (L+t) \times c \times (3.6 \times v) \) x9.81×10^{-3} =18.86 KN

\( C_x R \)

Load Slope Tension= \( \frac{2 \times 640}{3} \times 9.81 \times 10^{-3} = 14.91 \) KN

By adding all these values we got the Effective belt tension = 47.908KN.

\( T_e \times v \)

Power required\( = \frac{9550 \times 1000}{8.7 \times 0.5} \) =10 Hp.

Idler spacing\( = \frac{9550 \times 1000}{8.7 \times 0.5} \)

For carrying idler, idler spacing=175mm = 0.175meter

For return idler, idler spacing=2000mm= 2 meter.

Motor rating \( N=\frac{9550 \times 1000 \times P(FW)}{3} \)

=1500RPM.

Diameter of shaft \( d= \frac{16}{\pi \times (L+b \times M_b)^2 + (8 \times M_t) \times 2} \)
Diameter of shaft d is depends on various factors such as shear stress τ, Ks combined shock and fatigue factor applied to bending moment, Mb maximum bending moment, Kt combined shock and fatigue factor applied to torsional moment, Mt torsional moment. From bending moment diagram, \( M_b = 17.396 \times 10^6 \) Nmm. From table, for load to be applied gradually \( K_b = 1.5 \) and \( K_t = 1.0 \). The problems occurs due to the improper belt tension was observed.

Pulley diameter:

\[
D = N \times (1000-S) \times \pi \times V / (100 \times i_1 \times i_2 \times 1000 \times 60) = 636 \text{ mm.}
\]

Putting all these values in above equation we get, \( d = 138.24 \text{ mm.} \)

The purpose behind using this software is to get the correct belt tension and braking tension and empty load of running, accelerating and braking tension. Also it shows the belt effective tension, motor speed, power and gearbox speed reduction ratio. From the Belt Comp software the belt effective tension and power is observed as 50.0551 KN and 5.8KW etc.

Table 1 shows the full load of running, accelerating and braking tension and empty load of running, accelerating and braking tension. Also it shows the belt effective tension, motor speed, power and gearbox speed reduction ratio. From the Belt Comp software the belt effective tension and power is observed as 50.0551 KN and 5.8KW etc.

![Graph showing the tension plot at various stations](image)

Figure 2. Graph showing the tension plot at various stations

Different alternatives of pulley arrangements are tried by altering the horizontal and vertical distance between two consecutive pulleys. For each alternative the designed parameters like belt width, belt tension are calculated by using CEMA standard and some handbooks and those results are verified by using Belt Comp software.

![Table 1. Tension in KN in various stations](image)

Table 1. Tension in KN in various stations

<table>
<thead>
<tr>
<th>Station</th>
<th>Running</th>
<th>Accelerating</th>
<th>Braking</th>
<th>Running</th>
<th>Empty</th>
<th>Braking</th>
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</tr>
</tbody>
</table>

In the present paper the trials and analysis is carried out on belt conveyor system.

**Trials**

After the manufacturing and installation the trials are carried out on belt conveyor systems. The problems occurs during trial is overcome in analysis stage. The first trial was conducted with no load condition on the belt conveyor system. Only belt swivel was found out during this operation.

The second trial was conducted with mould without castings are allowed to pass over the cooling conveyor system. During this improper belt tension was observed.

The production starts with the first order of Slip Yoke. The rate production was 64 moulds/hr and weight of the casting was 50 kg. The pouring temperature was 1400°C. Due to high temperature of mould the belt gets elongate and the tension was poor.
The second order was of axle housing. The mould rate is 90 moulds/hr, casting weight was 70 kg, pouring temperature was 1394°C and the mould temperature was 40°C at the end of cooling conveyor. During this operation drive pulley was ideally rotating around the belt due to improper tension.

The third order was of P.V.Carrier. The mould rate 90 moulds / hr, casting weight was 75 kg, pouring temperature was 1395°C and the mould temperature was 70°C at the end of cooling conveyor. When the jacket and weight removed from the mould, then mould get expanded and cracked. When this cracked mould transfer to cooling conveyor, some sand was fallen down from the cooling conveyor.

Analysis

The problems encountered during trial phase are analyzed.

i) During the working of the conveyor system, the vibration of frame structure is observed. To overcome this vibration the structure is strengthened by providing (welding) channels between two columns as shown in the photograph 3.1.

![Photograph 3.1. Strengthening of frame structure](image)

ii) The return idler system is modified providing brackets to avoid accident as shown in the photograph 3.2.

![Photograph 3.2. Brackets for return idler](image)

iii) During trial it is observed that the belt tension is less and pulleys are revolving ideally. To build the tension one additional return idler is placed on the distance of 30m from tail pulley. Belt is placed below this idler. This idler is clamped on the channel. The vertical movement of the stud allows reducing and increasing the tension of belt. As shown in the photograph 3.3.

![Photograph 3.3. Use of return idler to increase belt tension](image)

iv) The snub pulley is lifted up by 20mm to increase the wrap angle between the drive pulley so that the tension at drive pulley is maintained properly. As shown in the photograph 3.4.

![Photograph 3.4. Lifting of snub pulley to increase wrap angle](image)

v) As the length of the conveyor system is 32.2 m, the belt swivel is major concern during its operation. This is maintained by providing the guide rollers and skirting rubber. When the system has to operate at some other load (tons per hour) i.e. change of casting, the system may requires some adjustment at the start in regards with belt tension, pulley adjustment etc.

vi) To avoid the sand wastage the skirt plate is provided near the pressure pulley. As shown in the photograph 3.5.

![Photograph 3.5. Skirt plate to prevent sand wastage](image)

The analysis is also can be done by taking following factors:

- The provision can be made to maintain the tension of belt automatically so that maintenance and breakdown can be reduced.
- The long types of conveyors can be designed and manufactured in two parts so that its manufacturing and installation will be easy.
- Self aligned spring loaded guide rollers, can be used so that belt swivel can be adjusted automatically.
- The bearing can be provided with the central pivoted bracket on return side of the conveyor so that belt swivel can be adjusted automatically.
- Advanced techniques like belt comp software, helix delta T software, belt analyst software and discrete event simulation can be used to get the correct profile and design of the conveyor system.
- Hold back system can be used to avoid reverse motion of belt. Intermediate return idlers can be provided with rubber lagging to reduce the swivel. The sensors can be providing at the beginning of the mould cooling conveyor, so that the temperature of mould, when the mould enters the mould cooling conveyor can be measured easily.
- The design of jacket and weight removal arrangement can be improved to avoid the cracking of mould by expansion during transferring of mould on the cooling conveyor. Belt sway switch can be used to allow the smooth running of the conveyor and protects it from damages by over swaying which can occur due to uneven loading of material, worn out idler roller bearings etc.
Conclusion

The major components and its parameters like belt capacity, belt width, effective belt tension, power, motor speed, diameter of shaft, idler spacing and diameter of pulley were designed successfully by using standard practice such as CEMA standard, Dunlop handbooks, available theories and software. The belt comp software was used to get the appropriate profile of pulley arrangement. Different alternatives of pulley arrangements are tried by altering the horizontal and vertical distance between two consecutive pulleys. For each alternative the designed parameters like belt width, belt tension etc. are calculated by using CEMA standard and Dunlop handbook and those results are verified by using belt comp software.

From the belt comp software the effective belt tension and power observed was 50.0551 KN and 5.8 KW etc. and from theoretical results the effective belt width and power was found to be 47.908 KN and 7.5 KW. So the results got from belt comp software found to be good agreement with the theoretical results.

The components like different types of pulleys namely drive pulley, tail pulley, pressure pulley, snub pulley and hold down pulley etc., carrying and return idlers, frame structures, and columns were manufactured successfully with the required dimensions and also from motor speed, power required, diameter of pulley, diameter of shaft the horizontal foot mounted PBL type geared motor and foot mounted Elecon type gear box was procured from manufacturer’s organization.

By using geared motor and gear box the jerk can be reduced by reducing the speed. The maximum speed reduction is carried out in geared motor i.e. 1500/48 = 31. The remaining speed reduction is carried out by using gear box. As the belt speed is 0.1 m/s and pulley diameter is 636 mm, the required rpm is 3. Hence the speed reduction in gear box is 48/3 = 16.

The installation of cooling conveyor system was carried out successfully by using water tube level arrangement. The advanced control switches like pull cord switch, zero speed switch were used to control the motion and to reduce the frequency of accidents in belt conveyor system. During trials, some of the difficulties were faced such as belt swivel was more, belt tension was poor, poor contact between drive pulley and belt resulted slippage, vibration of frame structure was more, sand wastage near the tail pulley, to overcome all the problems appropriate steps were taken during analysis.

Nomenclature

C: belt capacity in tons/hr
v: speed of belt in m/s
L: length of conveyor in m
H: height of conveyor in m
\( F_c, F_t \): equipment friction factor
W: weight of material and belt in kg
\( W_m, W_b \): weight of material per unit run in kg
\( c_t \): terminal friction constant
\( T_e \): effective belt tension in Newtons
s: idler spacing in meters
p: power in KW, Hp
M: torsional moment in Nmm
\( M_b \): bending moment in Nmm
D: diameter of pulley in meters
\( \mu \): coefficient of friction
p: external force in Newtons
g: gravitational acceleration in m/s²
N: speed of motor in RPM
d: diameter of shaft in mm
\( K_g \): combined shock and fatigue factor applied to bending moment
\( K_t \): combined shock and fatigue factor applied to torsional moment
\( \tau \): shear stress in N/mm²
\( \sigma_u \): ultimate tensile strength in N/mm²
\( \sigma_y \): yield strength in N/mm²
\( \eta \): fluid coupling slip in percentage
i: gear box speed reduction ratio
VLD: Vertical load diagram
HLD: Horizontal load diagram
VBMD: Vertical bending moment diagram
HBMD: Horizontal bending moment diagram
RBMD: Resultant bending moment diagram

References

[6] catalog of Bharatiya alloy and Steel cast limited, Gujarat (pp 1-12).