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

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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 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.

Introduction

Belt conveyor system is used to transport the material from one place to another place. It has high load carrying capacity, large length of conveying path, simple design, easy maintenance and high reliability of operation [1].

Belt conveyors are used as the principle components of some complex machines such as wheel excavator, conveyor bridges and much other type of hoisting and conveying machines.

Belt conveyors are used for various applications such as material transportation in foundry shop (supply and distribution of moulding sand, moulds and removal of wastes) coal and mining industry, sugar industry, automobile industry, Bagasse industry, fuel supply system of electric power stations etc.

From the literature [2] working and design specification of belt conveyor system are used. DISA moulding machine has following specifications: (Disa match 32X32 high pressure flaskless horizontal moulding line with disa cool) [2].

The following are the belt specifications

Material density=1600 Kg/m^3
Belt speed, v= 0.1 m/s
Length of conveyor, L=32.282 Meters
Height of conveyor, H=1.825 Meters
Inclination angle=3^0
Mould Size=833×833×650mm
Mould Temperature=180 degrees
Mould rate=100 moulds/hr.

From this specification the following parameters are designed in previous papers. Those parameters are:

Belt Capacity = 3.6 × load cross section area perpendicular to belt× belt speed × material density

Belt capacity =300tons/hr.

Belt Width = $\frac{T1\,(Kg)}{\text{Belt Strength}\,(Kg/inch)}$

T1 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_f) ×W×9.81×10^{-3} =14.13KN

Load Friction= F_l× (L+t_f) ×(c/ (3.6×v)) ×9.81×10^{-3} =18.86 KN

Load Slope Tension= $\frac{C \times H}{3.6 \times V}$ × 9.81 × 10^{-3} = 14.91 KN

By adding all these values we got the

Effective belt tension = 47.908KN.

Power required=$\frac{Te \times V}{33000}$ = 10 Hp.

Idler spacing= $\frac{8 \times Te \times Sag}{W \times 9.81 \times 10^{-3}}$

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

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

Motor rating N= $\frac{9550 \times 1000 \times P\,(KW)}{Mt}$ =1500RPM.

Diameter of shaft

$$d= \sqrt[3]{\left[\frac{16}{\pi \times t} \times \sqrt[2]{(Kb \times Mb)^2 + (Kt \times Mt)^2}\right]}$$

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Diameter of shaft d is depends on various factors such as shear stress τ, K_b combined shock and fatigue factor applied to bending moment, M_b maximum bending moment, K_t combined shock and fatigue factor applied to torsional moment, M_t torsional moment.
From bending moment diagram, M_b=17.396 ×10^6 Nmm
From table, for load to be applied gradually K_b=1.5 and K_t=1.0
Torsional moment M_t=47990334 Nmm
Putting all these values in above equation we get,
d= 138.24 mm.
Pulley diameter:
$D=N\times(100-S)\times\pi\times V/(100\times i\times i_c\times 1000\times 60) = 636mm.$
These designed parameters are verified by using Belt Comp Software.

Belt comp software is a powerful computer software package introduced to enable material handling design engineers with belt conveyor design and optimization. Belt comp highly dependable software to provide consistent, accurate and cost effective belt conveyor designs.

Some of the features of Belt comp program are as follows

(i)Belt comp is based on ISO/DIN/IS method of belt conveyor calculations using MKS units.

(ii) Belt comp data input is easy and it can cater for complex conveyor geometry including uphill and downhill configurations. It allows design of any length of belt conveyor without limit. The conveyor can be divided into as many as 24 stations as desired. Full loading, partial loading or unloading of any section is permitted for running special conveyor loading simulations. Fully empty condition is automatically calculated with any other condition. Any load case can be run to simulate any operating condition. In built check features alarms and ensures data entry error to a great extent. Editing of data is also very easy.

(iii) Belt comp provides a supreme feature of allowing any number of drives at virtually any pulley location. It also allows providing of brake on any pulley.

(iv)Belt comp automatically selects idler roll diameter and idler shaft diameter as a program default feature with all other properties required to proceed with the calculation. In addition it allows user to define idler features as a user's choice option or CEMA idler.

(v) Belt comp calculates six set of belt tensions simultaneously such as loaded running, loaded accelerating, loaded braking/coasting, empty running, empty accelerating, empty braking/coasting for all stations. It shows the maximum belt tension for each case.

The purpose behind using this software is to get the correct profile and to check the parameters which are calculated using different formulas. The given input are horizontal length between two stations/pulleys, lifts, diameter of pulley, angle of wrap, no. of scrappers, belt specification, idler specification, pulley specification etc. The outputs are motor rating effective tension, the tension among various stations, gear box ratio, and belt profile.The figure 1 shows the AutoCAD diagram of best pulley arrangements.

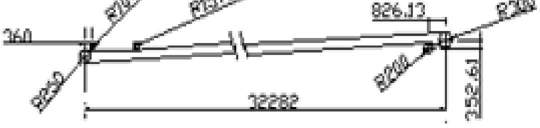


Figure 1. The Auto CAD diagram of best pulley arrangements

The table1 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.
Figure 2 shows the graph of tension plot at various stations from the Belt Comp software

Table 1. Tension in KN in various stations

	FULL LOAD			EMPTY		
Station	Running	Acceleratin	Braking	Running	Acceleratin	Braking
1	69.1925	69.1925	69.1925	69.1925	69.1925	69.1925
2	72.4029	72.6153	71.7021	69.3882	69.4415	69.3158
3	105.4166	106.2794	89.3625	69.5087	69.6527	69.3191
4	118.4194	127.6487	70.0149	70.0427	70.7247	68.7569
5	68.3642	67.8728	70.0149	68.2181	67.7899	68.7569
6	69.36	68.9459	70.3762	69.2323	68.8772	69.3327
7	69.1531	68.9206	69.4863	69.0254	68.8955	69.1045

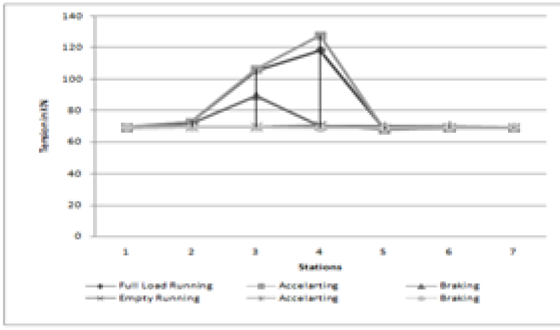


Figure 2. Graph showing the tension plot at various stations

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.

The effective belt tension and power required from theoretical design was found to be 47.908 KN and 5.3 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 pulley arrangement with which results are in close agreement with theoretical results has been selected. The best suited pulley arrangements are discussed above [3].
From these designed parameters the manufacturing and installation of belt conveyor system is discussed in previous papers [4].

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 1400^0 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 1394^0C and the mould temperature was 40^0C 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 1395^0C and the mould temperature was 70^0 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. Strengthning of frame structure

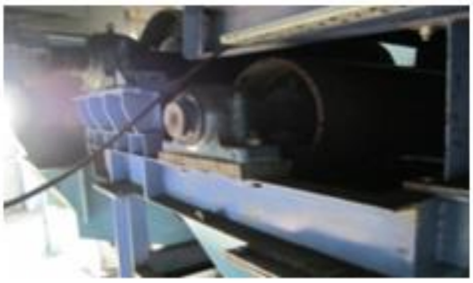
ii) The return idler system is modified providing brackets to avoid accident as shown in the photograph 3.2.

Photograph 3.2. Brackets for return idler

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

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

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

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, Fenner 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_e, F_l: equipment friction factor
W: weight of material and belt in $\frac{Kg}{m}$
W_m: weignt of material per unit run in Kg
W_b: weight of belt per unit run in kg
t_f: terminal friction constant
T_e: effective belt tension in Newtons
S_i: idler spacing in meters
p: power in KW, Hp
M_t: torsional moment in Nmm
M_b: bending moment in Nmm
D: diameter of pulley in meters
μ: coefficient of friction
F: external force in Newtons
g: gravitational acceleration in m/s^2
N: speed of motor in RPM
d: diameter of shaft in mm
K_b: combined shock and fatigue factor applied to bending moment
K_t: combined shock and fatigue factor applied to torsional moment
τ: shear stress in N/mm^2
σ_{ut}: ultimate tensile strength in N/mm^2
σ_{yt}: yield strength in N/mm^2
S: fluid coupling slip in percentage
i: gear box speed reduction ratio
i_c: belt 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

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