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Design and its Verification of Belt Conveyor System used for Cooling of Mould using Belt Comp Software

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1. ABSTRACT: Belt conveyor is the transportation of material from one location to another. Belt conveyor has high load carrying capacity, large length of conveying path, simple design, easy maintenance and high reliability of operation. Belt conveyor system is also used in material transport in foundry shop like supply and distribution of molding sand, molds and removal of waste. In this paper the study is carried out on DISA pattern moulding machine to meet the requirement of higher weight castings. The DISA machine is having the capacity of 100 moulds per hour. The mould size and density of material is given parameters. The present discussion aims to design the conveyor system used for cooling of mold, which includes speed, motor selection, belt specification, shaft diameter, pulley, idler spacing, gear box selection, with the help of standard practice and these results are verified with the belt comp software.
Keywords: Belt, Conveyor, DISA machine, Mould, Belt comp software.

2. INTRODUCTION:

Whenever the bulk material requires continuous transportation belt conveyors supply a reliable means. If the handling rate and total quantity warrant, they usually are the most economical. All lifting and conveying machines can be divided by their operating principles into two large groups:
(i)Intermittent motion, (ii) Continuous motion
Intermittent motion includes all types of cranes, lifts; surface transport means (trucks, loaders, prime move rs), aerial tramways and cable ways, scrappers and the like. Continuous motion includes conveyors, pneumatic and hydraulic transport means etc. which may generally called continuous transport machines or conveying machines.[1]
Continuous machines are characterized by non-stop motion of bulk or unit loads along a given path, without hallts for loading and unloading. The principle purpose of continuous conveying machine is to transport loads along a particular path. At the same time they can distribute loads among a number of destination points, deliver them to stores, transfer products from one technological operation to another and ensure the desired pace of a production process. [1]
Belt conveyors are employed for conveying various bulk and unit loads along horizontal or slightly inclined paths and for transporting articles between various operations in production flow lines.
Belt conveyors are used as the principle components of some complex machines such as wheel excavator, conveyor bridges and many 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.
Conveyors are again classified into different categories those are as follows: (i)chute conveyor (ii)wheel conveyor (iii) roller conveyor (iv)chain conveyor (v) slat conveyor (vi)flat belt conveyor (vii)magnetic belt conveyor (viii) troughed belt conveyor (ix) bucket conveyor (x)vibrating conveyor (xi) screw conveyor (xii) pneumatic conveyor (xiii) cart on track conveyor (xiv) tow conveyor (xv) trolley conveyor (xvi) power and free conveyor (xvii) monorail (xviii) Sortation conveyor.
From this classification the flat belt conveyor system is used throughout the whole paper.

3. DESIGN OF BELT CONVEYOR SYSTEM:

It is necessary to have design related basic information about various components of belt conveyor before attempting to design belt conveyor. The design of belt conveyor is depends upon design/construction of individual component.

3.1 Data available for belt conveyor system:

Input data used for designing the belt conveyor system are:

(Disa match 32X32 high pressure flaskless horizontal moulding line with disa cool).
Material density=1600 kg/m^3, Belt speed v = 0.1 m/s, Length of conveyor L = 32.282 meter, Height of conveyor, H = 1.825 meter, Inclination angle = 3°, Mould Size =833× 833× 650 mm, Mould Temperature = 180 degrees, Mould rate = 100 moulds/hr

3.2 Design procedure for belt conveyor system:

Note: Most of the formulas are in MKS units and for better understanding, converted into SI units.

The following procedure is followed to design present belt conveyor system:

3.2.1 Belt Capacity: [2]

BeltCapacity c= 3.6× load cross section area perpendicular to belt × belt speed× material density…….. (1)
$= 300\times 10^3$ kg/hr

3.2.2 .Belt Width: [3]

Belt width $= \frac{\mathrm{T1(Kg)}}{\mathrm{Belt\ Strength\ (Kg/inch)}}$ …….. (2)

Live load $= \frac{C}{3.6\times v}$ = 833.33 kg/m

Total live load (A)=live load ×conveyor length=26901.55 kg

Dead Load (B): This load consists of weight of roller, belting and drive pulley, therefore B=1419.5 kg

Belt Pull = (A+B)× coefficient of friction

For roller bed belt conveyor coefficient of friction= 0.05 Belt pull (c) = 1416.35 kg

Inclines/declines (D):

Tangent of angle= $33 \times \frac{\mathrm{Product\ Length}}{\mathrm{Product\ Height}}$ =42.28°

Additional belt pull =total live load × sine of angle =1408 kg

Additional belt pull =average live load × rise in elevation = 833.33×1.825 = 1400 kg

The maximum of above two is consider, D= 1408 kg

Deflectors (E): There are no deflectors in our system, $E = 0$

Transition point (F):

Additional belt pull= total live load × 0.05=1345.3 kg

Effective belt pull= total belt pull (C+D+E+F) × 1.25 =5212.14 kg

T_1 =effective belt pull× T_1factor

From table T_1factor = 1.42, therefore T_1 =7401.24 kg

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. Therefore, Belt Strength= 167.37kg/inch [4]

Substitute the value of belt strength and T_1 in equation (2),

Belt Width $= \frac{7401.24}{167.37}$ =1200mm

3.2.3 Belt Tension: [2]

Effective tension (Te) = total empty friction + load friction + load slope tension …….. (3)

Return side tension= $\mathrm{Fe} \times \mathrm{W} \times \mathrm{L} \times 0.4 \times 9.81 \times 10^{-3}$

For horizontal and elevating conveyors, Fe = 0.020

W=weight of material + weight of belt, kg/m

Weight of material, $W_m = \frac{C\times 2000}{60\times v}$

Weight of belt, W_b =16.6 lbs/ft, W= 780.88 kg/meter

Return side tension = 1.978 KN

Total empty friction = $F_e \times (L+ t_f) \times W \times 9.81\times 10^{-3}$

Standard edge distance= $0.055b + 0.9$ inch=0.0899 meter

For standard edge distance 0.0899 t_f= 60 meters

Total empty friction= 14.13 KN

Carrying side empty friction = Total empty friction - Return side tension = 12.15 KN

Load friction = $F_l \times (L+ t_f) \times \frac{c}{3.6\times v} \times 9.81\times 10^{-3}$

For horizontal and elevating conveyor, F_l = 0.025

Load friction=18.86 KN

Load slope tension= $\frac{C\times H}{3.6\times v} \times 9.81 \times 10^{-3}$ =14.91 KN

Effective Tension T_e = Total empty friction +load friction+ load slope tension =47.908KN

3.2.4 Power Calculation: [5]

Power HP= $\frac{Te\times v}{33000}$ ……………. (4)

Substituting the values in equation (4),

Power $= \frac{10777.452\times 19.68}{33000}$ = 7HP= 7×1.4 = 10 HP

3.2.5 Idler Spacing: [2]

Idler Spacing Si $= \frac{8\times Te\times Sag}{W\times 9.81\times 10^{-3}}$ ……… (5)

Sag = 0.02 (2%), Idler Spacing S_i= 1 Meters

3.2.6. Motor RPM calculation: [6]

Motor RPM, N= $\frac{9550\times 1000\times P(KW)}{Mt}$ ………. (6)

Here torque is not known and hence it can be calculated by following method. For belt conveyor application,

$M_t = \frac{1}{2} \times D \times (F + \mu wg)$ ………. (7)

To find out the diameter of roll

Material weight density=1600 kg/m^3. From table of bulk material handling handbook, for weight density of material W_m and belt width, the diameter of pulley D =0.630 meters [7]. According to CEMA (Conveyor Equipment and Manufacturers Association) the coefficient of friction μ =0.35[8]

Substitute the values of F, μ, W, and g in equation (7),

Torque M_t = 47990.334 Nm = 47990334 Nmm

Substitute the value of M_t in equation (6),

Motor RPM, = 1500RPM

3.2.7. Diameter of shaft: [09]

According to ASME standard, the diameter of shaft is calculated by following formula

$$d= \sqrt[3]{\left[\frac{16}{\pi\times\tau} \times \sqrt[2]{(Kb \times Mb)^2 + (Kt \times Mt)^2}\right]} \quad \ldots\ldots (8)$$

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. To finding the maximum bending moment following procedure is adopted. The figure 3.1 shows the bending moment diagram for shaft as the beam is simply supported at two ends. [10]

Vertical load diagram (VLD)

Let R_{Av} and R_{Dv} be the bearing reactions at A and D due to the vertical load. Now taking moment about A.

R_{Dv} = 123521 107.5 123521 1292.5

R_{Dv} = 12925 N

Also R_{Av} $_{Dv}$ = 123521+123521

R_{Av} = 123521 N

Vertical Bending Moment Diagram (VBMD):

Bending moment at A = 0

Bending moment at B=123521 107.5 =13278507.5 Nmm

Bending moment at C = 123521 107.5 = 13278507.5 Nmm

Bending moment at D = 0

Horizontal Load diagram (HLD)

Let R_{AH} and R_{DH} be the bearing reactions due to horizontal loads. Now taking moment about A

R_{DH} 1400 + 123521 107.5= 123521 1292.5

R_{DH} = 104551.70 N

Also R_{AH} + 104551.70 +123521 =123521

R_{AH} = 104551.70 N

Horizontal Bending Moment Diagram (HBMD)

Bending moment at A = 0

Bending moment at B=-104551.70 107.5=-11239308Nmm

Bending moment at C=104551.70 107.5=11239308 Nmm

Bending moment at D = 0

Resultant Bending Moment Diagram (RBMD)

Bending moment at A =0

Bending moment at B

17396574.54 Nmm

Bending moment at C

17396574.54 Nmm

Bending moment at D=0

Maximum bending moment, M_b = 17.396 10^6 Nmm

For load to be applied gradually K_b= 1.5 and K_t=1.0

For shaft material EN 8 AISI 1040 steel water quenched, fine grained temp at 540

Ultimate tensile strength $_{ut}$ mm^2

Yield strength $_y$ mm^2

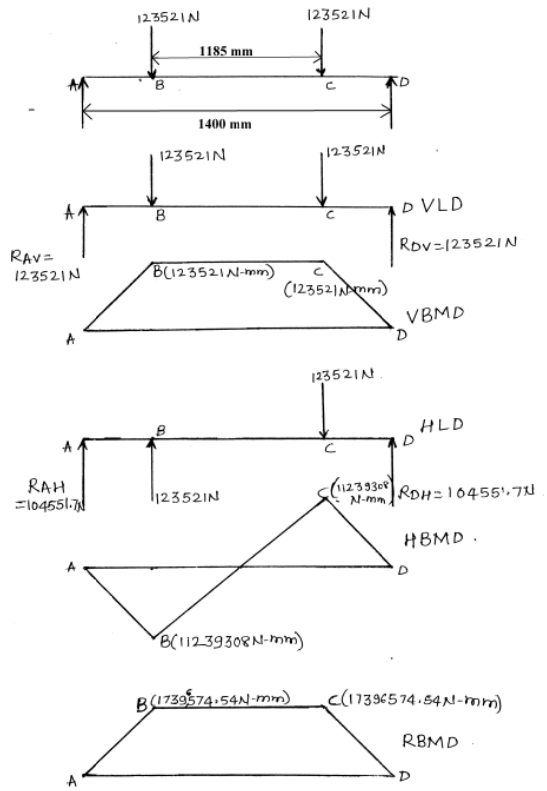

Figure3.1: Bending moment Diagram

From ASME code,

$_{max}$ = 0.3 yield strength in tension

$_{max}$ =177.9 N/mm^2

$_{max}$ = 0.18 ultimate strength in tension

$_{max}$ = 140.4 N/mm^2

Select minimum of above two values, $_{max}$ = 140.4 N/mm^2

Considering the key way effect,

= 0.75 $_{max}$ =105.3 N/mm^2

Substitute above values in equation (8)

d= 138.24 mm

3.2.8. Pulley Diameter: [11]

D ……….. (9)

Considering fluid is not forming a part of drive, S .

i=500:1, i_c = 1.0

Substitute all the values in equation (9), D= 636.619mm

From the diameter of pulley, the size of geared coupling is decided by using elecon catalogue. [12]

Sizes of geared couplings are as follows:

ED 500- geared motor to gear box

ED 4500- gear box to drum

To reduce the jerk we are reducing the speed by using geared motor and gear box. In the geared motor the speed reduction ratio is 1500/48 i.e.31. The maximum speed reduction is carried out in geared motor. The remaining speed reduction is carried out by using gear box. As the belt speed is 0.1m/s and pulley diameter is

636mm, the required rpm is 3. Hence the speed reduction in geared box is 48/3 i.e., 16.
The bearing selected from the shaft diameter and thrust is SN 230 spiral roller bearing (ZKL bearing). [13]
The specifications got after design are as follows:
Belt width=1200mm, Effective belt tension Te=47.908KN, Power=10hp, Idler spacing, S_i=1meter,Motor rpm=1500, Shaft diameter d=138.24mm, Pulley diameter=636.19mm
We are using belt comp software. From software we got the same results as in design

4. 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. Different profiles are studied and best profile is selected from the software. The figure 4.1 shows the AutoCAD (Elevation and plan) drawing prepared from the best suited profile. Table 1 shows the tension values while running, accelerating and braking during full load and empty conditions, figure 4.2 shows graph of the same.
Figure 4.3 shows the output of belt comp software form given inputs.

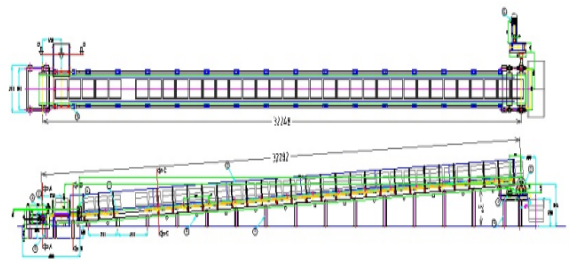

Figure 4.1: Belt Profile

Table1: Tension in KN at various stations.

	FULL LOAD			EMPTY		
Station	Running	Accelerating	Braking	Running	Accelerating	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

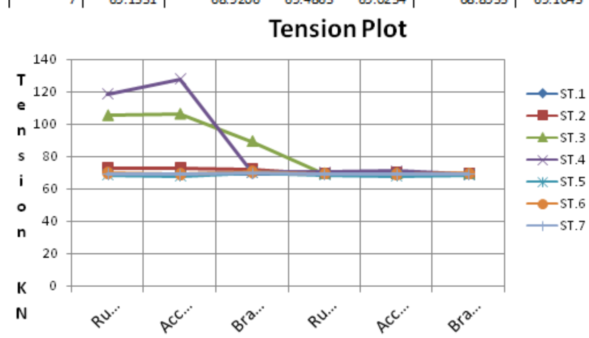

Figure4.2: Graph showing tension plot at various stations.

Figure 4.3: Output results of the belt comp software

5. CONCLUSION:

The major components and its parameters in the conveyor system are finalised. The designed parameters are calculated by using standard practice. The belt width is 1200 mm. The belt tension is 47.908 KN The drive is having power of 10HP with 1500 rpm. The shaft and pulley diameters are 140 and 636mm respectively. The spacing between the idler is 1 meter. The belt profile and tension plot has been found out using belt comp software, also other results like belt width, effective tension, motor rating, speed, speed reduction ratio, etc. are in good agreement with the theoretical results.

6. 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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