

## Design, Manufacture and Analysis of Belt Conveyor System used for Cooling of 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.

**Keywords** - Belt, Belt Comp software, Conveyor, DISA Machine, Mould.

### 1. 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

movers), aerial tramways and cable ways, scrapers 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 halts 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 [1].

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.

### 2. DESIGN OF BELT CONVEYOR SYSTEM

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<sup>3</sup>

Belt speed, v= 0.1 m/s

Length of conveyor, L=32.282 Meters

Height of conveyor, H=1.825 Meters

Inclination angle=3°

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 =  $\frac{T_1 (Kg)}{\text{Belt Strength } h (Kg/inch)}$

T<sub>1</sub> 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<sub>e</sub>) = Total empty friction + Load friction + Load slope tension

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

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

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

By adding all these values we got the

Effective belt tension = 47.908KN.

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

Idler spacing =  $\frac{8 \times T_e \times S_{ag}}{W \times 9.81 \times 10^{-3}}$

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

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

Motor RPM,  $N = \frac{9550 \times 1000 \times P (KW)}{M_t} = 1500 \text{ rpm.}$

Diameter of Shaft, d

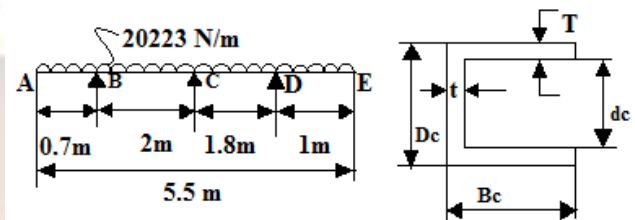
$= \sqrt[3]{\left[ \frac{16}{\pi \times \tau} \times \sqrt{(K_b \times M_b)^2 + (K_t \times M_t)^2} \right]} = 138.24 \text{ mm.}$

Pulley Diameter,  $D = \frac{N \times (100 - S)}{100} \times \frac{1}{i \times i_c} \times \frac{\pi \times V}{1000} \times \frac{1}{60} = 636.619 \text{ mm}$

Frame: Mild Steel Material is used for frame. Table 2 shows the specification of channel for size MC 100 [3].

**Table 1: The specification of channel for size MC 100**

Designation	Mass (kg/m)	Sectional area (cm <sup>2</sup> )	Dimensions (mm)			
			D	B	t	T
MC 100	9.56	12.2	100	50	5	7.7



**Figure 1: Reactions at Frame Support and sectional view of Channel for size MC100**

Figure 1 shows the reaction at frame support, the uniform distributed beam is supported at three ends. To find out the reactions at three ends namely B, C and D the following steps are to be carried out.

Step 1: Reactions at B, C, and D

Taking moment about B,  $\Sigma M_B = 0$

$$-2R_C - 3.8R_D - 4923.422 + 40191.2 + 104899.032 + 86411.08 = 0$$

$$2R_C + 3.8R_D = 226577.89 \dots\dots\dots (1)$$

Taking moment about C,  $\Sigma M_C = 0$

$$2R_B - 1.8R_D + 5526.29 = 0 \dots\dots\dots (2)$$

Taking moment about D,  $\Sigma M_D = 0$

$$3.8R_B + 1.8R_C = 193420.15 \dots\dots\dots (3)$$

The Modulus of rigidity of Mild Steel Material is  $E = 206 \text{ GPa} = 206 \times 10^9 \text{ N/m}^2$

The moment of inertia for C cross-section for the size MC100 is given by

$$I = \frac{BD^3}{12} - \frac{(B-t)(D-2T)^3}{12}$$

$$I = \frac{50 \times 100^3}{12} - \frac{(50-5)(100-15.4)^3}{12}$$

$$I = 1.897 \times 10^6 \text{ mm}^4 = 1.897 \times 10^{-6} \text{ m}^4$$

$Y = D_C / 2 = 50 \text{ mm}$

$$\delta_{\max} = \frac{5WL^4}{384EI} = \frac{5 \times 20095.6 \times 3.8^4}{384 \times 206 \times 10^9 \times 1.897 \times 10^{-6}}$$

$$\delta_{\max} = 0.1396 \text{ m}$$

Also,

$$\delta_{\max} = R_C \times b \times (L^2 - b^2)^{(3/2)} / 9 \times \sqrt{3} \times E \times I \times L$$

Here  $b = 3.8 \text{ m}$

Substituting all the values we get,

$$R_C = 47902.46 \text{ N}$$

Substitute  $R_C$  value in equation (1), we get

$$R_D = 34413.94 \text{ N}$$

Substitute  $R_C$  value in equation (3), we get

$$R_B = 28209.4 \text{ N}$$

Step 2: Bending Moment Calculation

B.M. at A=0  
 B.M. at B= 20095.6×0.7×0.35=4923.422 N-m  
 B.M. at C=20095.6×2.7×1.35-28209.4×2=16829.662 N-m  
 B.M. at D= 20095.6×1×0.5=10047.8 N-m  
 B.M. at E=0  
 Maximum bending moment,  
 B.M.<sub>max</sub>=  

$$\sqrt{(4923.422)^2 + (16829.662)^2 + (10047.8)^2}$$
  
 Maximum bending moment, B.M.<sub>max</sub>=20.21×10<sup>3</sup> N-m  
 = 20.21×10<sup>6</sup> N-mm

### Step 3: Bending Stress Calculation

Bending stress,  $\sigma_b = MY/I$

Substitute the value of M (bending moment), Y and I in above equation we get

Bending stress,  $\sigma_b = 532.68 \text{ N/mm}^2$

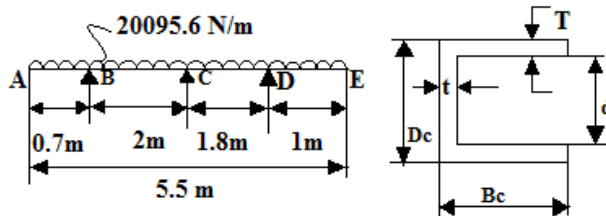
Since the allowable stress of mild steel is 250 N/mm<sup>2</sup>

Bending stress exceeds the value of allowable stress. Therefore the design is not safe. Design is checked for next property of C cross section.

Table 2 shows the specification of channel for size MC 200.

**Table 2: The specification of channel for size MC 200**

Designation	Mass (kg/m)	Sectional area (cm <sup>2</sup> )	Dimensions (mm)			
			D	B	t	T
MC 200	22.3	28.5	200	75	6.2	11.4



**Figure 2: Reactions at frame support and sectional view of Channel for size MC200**

Figure 2 shows the reaction at frame support, the uniform distributed beam is supported at three ends. To find out the reactions at three ends namely B, C and D the following steps are to be carried out.

### Step 1: Reactions at B, C, and D

Taking moment about B,  $\Sigma M_B = 0$

$$-2R_C - 3.8R_D - 4954.635 + 40446 + 105564.06 + 86958.9 = 0$$

$$2R_C + 3.8R_D = 228014.32 \quad \dots\dots\dots (1)$$

Taking moment about C,  $\Sigma M_C = 0$

$$2R_B - 1.8R_D - 33266.835 - 40446 + 32761.26 + 46512.9 = 0$$

$$2R_B - 1.8R_D + 5561.325 = 0 \quad \dots\dots\dots (2)$$

Taking moment about D,  $\Sigma M_D = 0$

$$3.8R_B + 1.8R_C - 58747.815 - 113248.8 -$$

$$32761.26 + 10111.5 = 0$$

$$3.8R_B + 1.8R_C = 194646.375 \quad \dots\dots\dots (3)$$

The Modulus of rigidity of Mild Steel Material is  $E = 206 \text{ GPa} = 206 \times 10^9 \text{ N/m}^2$

The moment of inertia for C cross-section for the size MC200 is given by

$$I = B_C D_C^3 / 12 - ((B_C - t) \times d_C^3) / 12$$

$$I = \frac{75 \times 200^3}{12} - \frac{(75 - 6.2) \times 177.2^3}{12}$$

$$I = 18.1 \times 10^6 \text{ mm}^4$$

$$Y = D_C / 2 = 100 \text{ mm}$$

$$\delta_{\max} = \frac{5WL^4}{384EI} = \frac{5 \times 20223 \times 3.8^4}{384 \times 206 \times 10^9 \times 18.1 \times 10^{-6}}$$

$$\delta_{\max} = 0.014 \text{ m}$$

Also,

$$\delta_{\max} = R_C \times b \times (L^2 - b^2)^{(3/2)} / 9 \times \sqrt{3} \times E \times I \times L$$

here  $b = 3.8 \text{ m}$

substituting all the values we get,

$$R_C = 46504.32 \text{ N}$$

Substitute  $R_C$  value in equation (1), we get

$$R_D = 35527.81 \text{ N}$$

Substitute  $R_C$  value in equation (3), we get

$$R_B = 29194.37 \text{ N}$$

### Step 2: Bending Moment Calculation

B.M. at A=0

$$\text{B.M. at B} = 20223 \times 0.7 \times 0.35 = 4954.63 \text{ N-m}$$

$$\text{B.M. at C} = 20223 \times 2.7 \times 1.35 - 29194.37 \times 2 = 15324.095 \text{ N-m}$$

$$\text{B.M. at D} = 20223 \times 1 \times 0.5 = 10111.5 \text{ N-m}$$

B.M. at E=0

Maximum bending moment,

$$\text{B.M.}_{\max} =$$

$$\sqrt{(4954.63)^2 + (15324.095)^2 + (10111.5)^2}$$

$$\text{Maximum bending moment, B.M.}_{\max} = 19.016 \times 10^3 \text{ N-m}$$

$$= 19.016 \times 10^6 \text{ N-mm}$$

### Step 3: Bending Stress Calculation

Bending stress,  $\sigma_b = MY/I$

Substitute the value of M (bending moment), Y and I in above equation we get

$$\text{Bending stress, } \sigma_b = 105.06 \text{ N/mm}^2$$

Since the allowable stress of mild steel is 250 N/mm<sup>2</sup>

Bending stress is less than value of allowable stress.

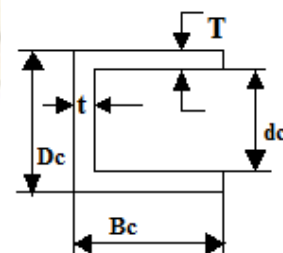
Therefore the design is safe.

Therefore frame size used is MC 200.

Column Size: Mild Steel material is used for design the column.

Referring table 1,  $D_C = 100 \text{ mm}$ ,  $T = 7.7 \text{ mm}$ ,  $t = 5.0 \text{ mm}$ ,  $B_C = 50 \text{ mm}$  the moment of inertia for C cross section is calculated by following method.

The properties of C cross section are as follows:



**Figure 3: Sectional view of Channel for size MC100**

Moment of inertia for C cross section is given by

$$I = B_C D_C^3 / 12 - ((B_C - t) \times d_C^3) / 12$$

$$I = \frac{50 \times 100^3}{12} - \frac{(50 - 5) \times 84.6^3}{12}$$

$$I = 1.89 \times 10^6 \text{ mm}^4$$



From table 1 Area of Cross Section  $A = 12.2 \text{ cm}^2 = 1220 \text{ mm}^2$

Slenderness Ratio =  $l/k$

Radius of gyration  $k = \sqrt{I/A} = \sqrt{1.89 \times 10^6 / 1220} = 39.35 \text{ mm}$

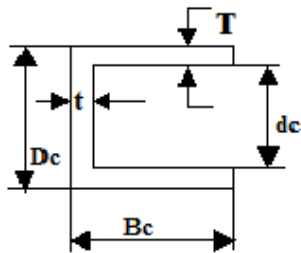
Length of column  $l = 1620 \text{ mm}$

Slenderness ratio =  $1620/39.35 = 41.16$

Here slenderness ratio is  $> 30$ , so buckling effect takes place. Design is not safe for this property of C cross section of column.

Design is checked for next property of C cross section.

Referring table 2,  $D_c = 200 \text{ mm}$ ,  $T = 11.4 \text{ mm}$ ,  $t = 6.2 \text{ mm}$ ,  $B_c = 75 \text{ mm}$  the moment of inertia for C cross section is calculated by following method.



**Figure 4: Sectional view of Channel for size MC 200**

Moment of Inertia is given by,

$$I = \frac{B_c D_c^3}{12} - \frac{(B_c - t) \times d_c^3}{12}$$

$$I = \frac{75 \times 200^3}{12} - \frac{(75 - 6.2) \times 177.2^3}{12}$$

$$I = 18.1 \times 10^6 \text{ mm}^4$$

From above table 2, Area of cross section  $A = 28.5 \text{ cm}^2 = 2850 \text{ mm}^2$

Slenderness Ratio =  $l/k$

Length of column  $l = 1620 \text{ mm}$

Radius of gyration  $k = \sqrt{I/A} = \sqrt{18.1 \times 10^6 / 2850} = 79.89 \text{ mm} \approx 80 \text{ mm}$

Slenderness ratio =  $1620/80 = 20.25$

Here Slenderness ratio is  $< 30$ , therefore no buckling takes place. The design is safe for column size MC 200. Therefore column size used is MC 200.

### 3. MANUFACTURING

3.1 Pulley: Pulleys are necessary in conveyors to change the direction of belt in vertical planes and to form endless loop for continuous motion.

Five types of pulleys are used, those are [4]:

3.1.1. Drive Pulley: The pulley at the discharge end of conveyor may be either an idler or drive pulley. Usually has larger diameter than other pulley in the system and often lagged to increase the traction and pulley life.

3.1.2. Snub Pulley: This pulley mounted close to the drive pulley on return side of the belt the snubs pulleys primary job is to increase the angle of wrap around the drive pulley, thereby increasing traction its second purpose reducing belt tension which is important in maximizing conveyor component life.

3.1.3. Tail Pulley: Tail Pulley a pulley at the tail of the belt conveyor opposite the normal discharge end; may

be a drive pulley or an idler pulley. Tail pulleys are also useful in maintaining proper tension in the belt.

3.1.4. Pressure Pulley: It is non drive pulley located after the tail pulley on carrying side of the belt. Its primary function is to maintain the pressure.

3.1.5. Hold Down Pulley: It is also a nondrive pulley located after the pressure pulley, it helps to maintain the straightness of the belt during inclination for easy loading of material to be conveyed.

3.2. Geared Motor and Gear Box: Based on the design, the motor speed 1500 rpm, power 10hp, diameter of shaft 138.24mm, diameter of pulley 636.10 mm geared motor and gear box are procured from the manufacturing organization.

3.3. Idlers: Idler is made up of mild steel material. For 1200 mm belt width, the idler diameter 139.7 is used.

3.4 Frame: Based on the design, frame is manufactured for size MC 200.

3.5. Column: Based on the design, column is manufactured for size MC 200 [4].

After the manufacturing, the installation of belt conveyor system is done at manufacturing site.

**4. 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  $1400^\circ \text{C}$ . 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  $1394^\circ \text{C}$  and the mould temperature was  $40^\circ \text{C}$  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  $1395^\circ \text{C}$  and the mould temperature was  $70^\circ \text{C}$  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.

### 5. ANALYSIS:

The problems encountered during trial phase are analyzed.

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.

The return idler system is modified providing brackets to avoid accident.

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.

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.

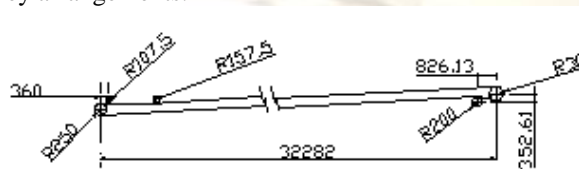
To avoid the sand wastage the skirt plate is provided near the pressure pulley.

In the analysis, the design parameters are verified by using Belt Comp Software.

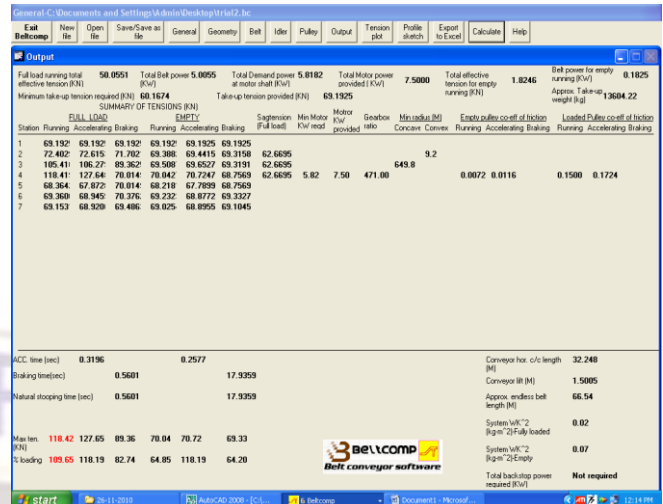
Belt Comp software is a powerful computer software package introduced to enable material handling design engineers with belt conveyor design and optimization. Belt comp software is highly dependable software to provide consistent, accurate and cost effective belt conveyor designs.

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. 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 pulley arrangement with which results are in close agreement with theoretical results has been selected.

Figure 5 shows the AutoCAD diagram of best suited pulley arrangements.



**Figure 5: The Auto CAD diagram of best pulley arrangements**



**Photograph 1: The Computer screen of belt comp software output.**

The photograph 1 shows the computer screen of belt comp software output. The above photograph 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. In the above photograph belt effective tension and power is observed as 50.0551 KN and 5.8KW etc.



**Photograph 2: Computer screen of belt comp software tension plot.**

The photograph 2 shows the tension plot of belt comp software. It shows the graph of station number versus the tension (KN). In this photograph tensions like full load running, full load accelerating, full load braking, Empty running, empty accelerating and empty braking are shown at each station number.

The effective belt tension and power required from theoretical design was found to be 47.908 KN and 5.3 KW etc.

The best alternative of pulley arrangement gives nearly close results as that of the theoretical results. The best alternative is discussed above.

Hence, it is verified that Belt Comp software results are in close agreement of the theoretical results.

## 6. 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 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.

## 7. NOMENCLATURE

Symbol	Description
C	Belt Capacity
V	Belt Speed
L	Length of Conveyor
H	Height of Conveyor
W	Total weight of the conveyor
$W_m$	Weight of Material per unit run
$W_b$	Weight of Belt per unit run
$T_e$	Effective belt tension
$S_i$	Idler spacing
P	Power
$M_i$	Torsional moment
$M_b$	Bending Moment
D	Diameter of pulley
F	External force
G	Gravitational acceleration
N	Speed of motor
D	Diameter of shaft
T	Shear stress
$\sigma_{ut}$	Ultimate tensile strength
$\sigma_{yt}$	Yield strength
S	Fluid coupling slip
I	Moment of Inertia
$\delta_{max}$	Maximum deflection
$\sigma_b$	Bending stress
K	Radius of gyration
$D_c$	Depth of channel
$B_c$	Width of channel
T	Web of channel
T	Thickness of channel
$R_B, R_C, R_D$	Reactions at B, C and D

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