Design of Belt Conveyor System

Ulkesh Solanki[1] Amol Shroff[2] Tejas Kulkarni[3] Prashant Waghmare[4] K.P. Agte[5]
[1,2,3,4]Student [5]Assitant Professor
[1,2,3,4,5]Depatrment of Mechanical Engineering
[1,2,3,4,5]Smt. KashibaiNavale College of Engineering, Sinhgad Institutes, Pune, India

Abstract— The article gives information about design of belt conveyor system. The components of belt conveyor system like belt, driving motor, driving and return pulley and rollers are designed. The conveyor system designed in following article is used to convey powder type raw material.

Keywords: Belt, Conveyor system, Material handling equipment

I. INTRODUCTION

While designing a system for transport of raw materials or finished products, the choice of the method for transport must favour the most cost effective solution for the volume of material moved, the plant and its maintenance, its flexibility for adaptation and its ability to carry a variety of loads and even be overloaded at times. Use of belt conveyor as a method of conveying satisfies the above selection criteria. This article aims at providing a complete solution for design of belt conveyor system to one of the actual raw materialconveying problem. The basic components of a belt conveyor system are shown in Fig 8.1.

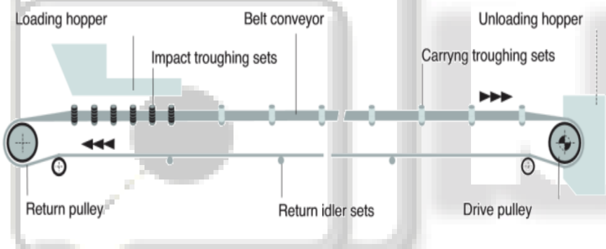

Fig. 1: Basic drawing of a belt conveyor

II. INPUT DATA

For designing a conveyor belt, some basic information needed is given below.

- Specific weight of material to be conveyed (ρ) = 2.5 t/m^3.
- Lump size = 50-100mm
- Distance between the centers (L) = 4m
- Belt Load (I_V) – 30 t/h
- Angle Surcharge (β) – 20^o

III. DESIGN OF BELT

A. Belt Speed:

From experimental data Table 8.1 shows the maximum belt speeds advised considering the lump size of the conveyed material and the width of the belt in use.

Lump size (Max dimension)		**Max speed**			
Uniform up to mm	**Mixed up to mm**	**A**	**B**	**C**	**D**
50	100	2.5	2.3	2	1.65
75	150	2.5	2.3	2	1.65
125	200	3	2.75	2.38	2
170	300	3.5	3.2	2.75	2.35
250	400	4	3.65	3.15	2.65
350	500	4	3.65	3.15	2.65
400	600	4.5	4	3.5	3
450	650	4.5	4	3.5	3

Table 1: selection parameter for speed of conveyor

- Material with specific weight 0.5 to 1 t/m^3
- Material with specific weight 1 to 1.5 t/m^3
- Material with specific weight 1.5 to 2 t/m^3
- Material with specific weight 2 to 2.5t/m^3

The material to be conveyed in our case is of type - D. Referring the table speed is taken as(v = 1 m/s) which is less than the maximum allowable speed of 1.6m/s

B. Belt Width:

The belt width can be determined by using the information ofloaded volume. The volumetric load (I_M) on the belt is given by the formula:

$$I_M = I_V/\rho$$
$$= 30/2.5$$
$$= 12\ m^3/h$$

For v = 1 m/s

$$I_{VT} = I_M/v$$
$$= 12\ m^3/h$$

The belt width considering the design for 2 troughing sets is selected from following table

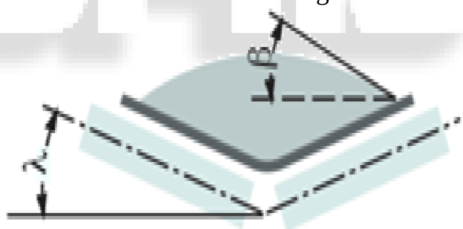

Fig. 2: Loaded volume with 2 roll troughingset
v=1m/s

Belt width mm	**Angle of surcharge (β)**	**I_{VTm3}/h**
300	20	28.8
400	20	55.8
500	20	92.8
600	20	165.9

From above table belt width is selected as w = 300mm

C. Tangential force:

The first step is to calculate the total tangential force ($F_{U)}$ at the periphery of the drive pulley. The total tangential force must overcome all the resistance that comes from motion and consists of the sum of the following forces:

- Force necessary to move the loaded belt must overcome the belt frictional forces from the carrying troughing sets upper and lower and the pulleys.

- Force necessary to overcome the resistance as applied to the horizontal movement of the material.
- Force necessary to raise the material to the required height (in the case of a decline, the force generated by the mass changes the resultant power).
- Force necessary to overcome the secondary resistances where accessories are present. (Trippers, cleaners, scrapers, rubber skirts, reversing units etc.)

The total tangential force F_U at the drive pulley periphery is given by:

$F_U = [L \times C_q \times C_t \times f\ (2\ q_b + q_G + q_{RU} + q_{RO}) + (q_G \times H)] \times 9.81$ N -- i

where:

- L=Centres of conveyor (m)
- C_q=Fixed coefficient of resistance (belt accessories)[From Table – 3.4]
- C_t = Passive coefficient of resistance [From Table – 3.5]
- f=Coefficient of friction internal rotating parts,[From Table – 3.6]
- q_b= Belt weight per linear metre in Kg/m, (sum of cover and core weight)
- q_G =Weight of conveyed material per linear metre Kg/m
- q_{RU} =Weight of lower rotating parts in Kg/m
- q_{RO} =Weight of upper rotating parts in Kg/m
- H=Height change of belt.

Centres M	**Cq**
4	5.2
10	4.5
20	3.2
30	2.6

Table 3: Coefficient of fixed resistance

Temperature (^{0}C)	20	10	0	-10	-20
Factor (Ct)	1	1.01	1.04	1.10	1.16

Table 4: coefficient of passive resistance given by temperature

Speed (m/s)	**1**	**2**	**3**
Coefficient of internal friction (f)	0.0160	0.0165	0.0170

Table 5: Coefficient of internal friction (f) of materials and of rotating parts

Considering a belt resistance class 125 N/mm with a cover thickness 4+2(Refer Table 3.10), the belt weight per linear meter is

q_b=3.9kg/m

$q_G = I_V / 3.6 \times v$

= 8.33 kg/m

q_{RU} = weight of upper rotating parts/upper troughing set pitch(a_O)

= 5/1

= 5 kg/m

q_{RO} = weight of lower rotating parts/return set roller pitch(a_U)

= 4/2

= 2 kg/m

Substituting all the values in equation (i) we get

F_U = 311.50 N

D. Maximum Belt Tension:

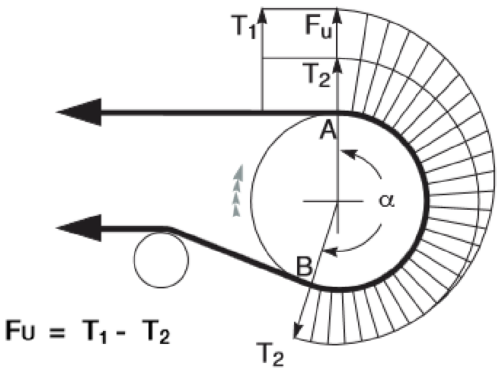

Fig. 3: Tangential force at pulley

The total tangential force F_U at the pulley circumference corresponds to the differences between tensions T_1 (tight side) and T_2 (output side). From these is derived the necessary torque to begin to move the belt and transmit power.

The relationship between T_1 and T_2 is given as

$T_1/T_2 = e^{\mu\theta}$

But, $T_1 = F_U + T_2$

So, $T_2 = F_U /(e^{\mu\theta} - 1)$

$= F_U \times C_W$

T_2 = 155.74 N

(C_W is wrap factor, which is a function of the angle of wrap of the belt on the drive pulley and the value of the coefficient of friction between the belt and pulley.)

Value of C_W here is 0.5 for the lagged pulley

Now, $T_1 = F_U + T_2$

= 467.23 N

The maximum working tension of the belt $T_{u\ max}$ is given as

(The factor of safety f_s for belts with textile inserts is taken as 10)

$T_{u\ max} = T_1 \times f_s/w$

= 11.68 N/mm

The belt considered in the initial data of this calculation is having maximum permissible belt tension of 12.5 N/mm which is greater than the actual maximum tension. Thus the assumption of belt is safe.

Belt range	**Max. permissible tension Kg/cm**	**Fabric type**	**No. of piles**	**Covers (mm)**	**Belt thickness (mm)**	**Belt weight Kg/cm^2**
EP 250	12.5	EP 125	2	(4+2)	8.5	9.77

Table 6: Belt Specification

IV. POWER RATING OF MOTOR

We consider the reduction gear efficiency (η) as 0.86. Thus the required power to rotate the conveyor system is given as

$P = F_U \times v/1000 \times \eta$

= 0.36kw

= 0.5Hp

V. DESIGN OF PULLEYS

A. *Pulley Diameters:*

Belt breaking load (N/mm)	Motorised pulley (mm)	Return Pulley (mm)
12.5	200	160

The diameters of Driving and Return pulley is selected from above table.

B. *Driving Pulley:*

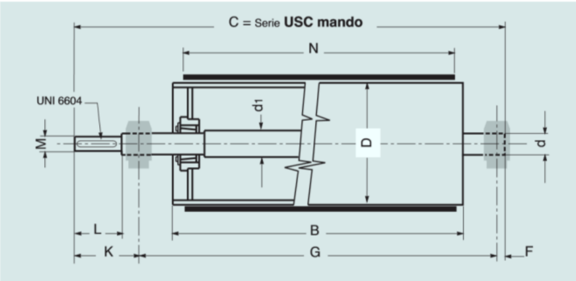

Fig. 4: Driving Pulley

For given belt width of 300mm, a USC series of drive pulley with clamping units is selected from standard table. The specifications of the selected pulley are as follows:

Pulley Type – USC
D – 190mm
B – 500mm
d – 40mm
C – 840mm
d1- 45mm
M m6 – 38mm
L – 80mm
K – 145mm
F – 45mm
G – 660mm
Speed of Pulley = v x 60 / π x D

= 70 rpm

C. *Return Pulley:*

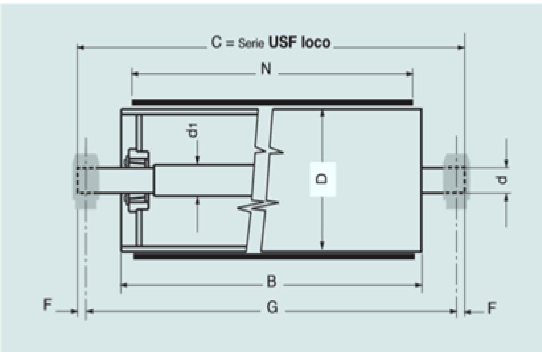

Fig 5: Return Pulley

For given belt width of 300mm, a USF series of return pulley with clamping units is selected from standard table. The specifications of the selected pulley are as follows:

Pulley Type – USF
D – 160mm
B – 500mm
d – 40mm
C – 710mm
d1 – 45mm
F – 25mm
G – 660mm

VI. DESIGN OF ROLLERS

A. *Troughing Set:*

There are 2 basic types of troughing set base frame: the upper set, which carries the loaded belt on the upper strand, and the lower set, which supports the empty belt on the return strand.

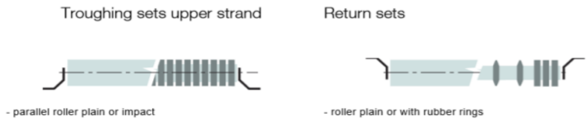

Fig. 6: Troughing set

The trough set pitch details are shown in figure below

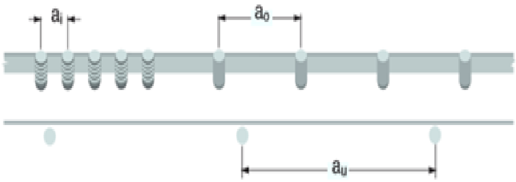

Fig. 7: Trough set pitch

The trough set pitch for the upper strand of a belt conveyor(a_O), and for the return strand (a_U) is selected from the following table.

Belt width (mm)	Pitch of sets	
	Upper	Lower
300	1.65	1.50

Table 8: Maximum Pitch of sets

Considering the centre to centre distance of pulleys and maximum pitch of sets, the trough set pitch values are considered as follows

- a_O= 1.0m
- a_U= 2.0m
- a_i = 0.5m
- Number of Carryingtroughing sets – 3
- Number of Impact troughing sets – 1
- Number of Return idler sets – 1

B. *Selection of Roller Type:*

Roller series RTL is best suited for this design purpose as it is specially designed for movement of light loads. The rollers consist of steel tube which is coated with soft and anti-abrasive rubber. Bearing housings are made of technopolymers which are resistant to mechanical forces and corrosion.Roller series RTL is best suited for this design purpose as it is specially designed for movement of light loads.

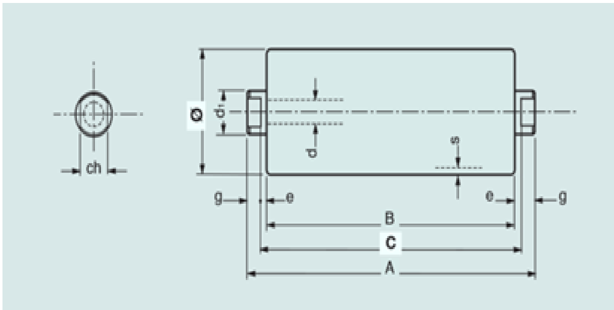

Fig. 8: Roller series RTL

C. Selection of Roller Diameter

The relationship between the maximum belt speed, the roller diameter and its relative number of revolutions is shown in the table below

Roller diameter mm	Belt speed m/s	Rpm n
50	1	382
63	2	606
76	2.5	628

Table 9: Minimum Roller diameter for specific belt speed

For given belt speed of 1m/s the roller diameter of 50mm is selected.

D. Calculation of Load on the Rollers:

The principal operating factors involved in calculation of load on the rollers are:

- I_v = belt load (t/h)
- a_o= pitch of carrying trough set (m)
- a_u = pitch of return set (m)
- q_b = weight of belt per linear metre (Kg/m)
- F_p = participating factor of the highest stressed roller (Tab.3.11)
- F_d = shock factor see Tab.20 (depends on lump size of material) Fs = service factor (Tab.3.12)
- F_m = ambient factor (Tab.3.13)
- F_v = speed factor (Tab. 3.14)
- F_s = service factor (Tab 3.15)

0° 	20° 	20° 
1.00	0.50	0.60

Table 10: Participation Factor (F_P)

Condition	F_m
Clean and with regular maintenance	0.9
Presence of abrasive or corrosive materials	1
Presence of very abrasive or very corrosive materials	1.1

Table 11: Environmental Factor (F_m)

Lump size	Belt speed m/s		
	1	2.5	3
0/100mm	1	1	1
100/150mm	1.02	1.06	1.09
150/300mm	1.04	1.06	1.09

Table 12: Shock Factor (F_d)

Belt Speed (m/s)	Roller Diameter (mm)		
	50	60	76
0.5	0.82	0.81	0.80
1.0	0.97	0.92	0.87
1.5	1.00	0.99	0.99

Table 13: Speed Factor (F_v)

Working life	Fs
Less than 6 hours per day	0.8
From 6 to 9 hours per day	1
From 10 to 16 hours per day	1.1
Over 16hours per day	1.2

Table 14: Service Factor (F_s)

E. For Carrying Troughing Set

The static load C_a on the carrying troughing set is determined, using the following formula:

$C_a = a_o \times (q_b + (I_v/3.6 \times v)) \times 9.81$ N

$= 1 \times (3.9 + (30/3.6 \times 1)) \times 9.81$

$C_a = 120.01$ N

Multiplying it using the operating factors we have the dynamic load C_{a1} as:

$C_{a1} = C_a \times F_d \times F_s \times F_m$ N

$= 120.01 \times 1 \times 1 \times 0.9$

$C_{a1} = 108.00$ N

Multiplying it by the participation factors one obtains the load c_a on the highest stressed roller.

$c_a = C_{a1} \times F_p$ N

$= 108.00 \times 0.5$

$c_a = 54.00$ N

For the determined load capacity of carrying troughing set, the specifications of selected roller type are as follows:

Arrangement – Two troughing sets
Ø – 50mm
B – 200mm
C – 208mm
A – 226mm
Weight of rotating part – 1.6kg
Load capacity – 56N
d – 15mm
d1 – 20mm
ch – 14 mm
s – 2mm
e – 4mm
g – 9mm

F. For Return Set:

The static load on the return set, Cr (not needing to take account of the material weight) is determined from the following formula :

$C_r = a_u \times q_b \times 9.81$ N

$= 2 \times 3.9 \times 9.81$

$C_r = 76.52$ N

The dynamic load on the return set will be :

$C_{r1} = C_r \times F_s \times F_m \times F_v$ N

$= 76.52 \times 1 \times 0.9 \times 0.97$

$C_{r1} = 66.80$ N

Which will be similar to the load on the single return roller :

$C_r = C_{r1} \times F_p$ N

$= 66.80 \times 1$

$C_r = 66.80$ N

For the determined load capacity of return set, the specifications of selected roller type are as follows:

Arrangement – Single Flat roller set
Ø – 50mm
B – 380mm
C – 388mm
A – 406mm
Weight of rotating part – 4.0kg
Load capacity – 71N
d – 15mm
d1 – 20mm
ch – 14 mm
s – 2mm
e – 4mm

g – 9mm

VII. CONCLUSION

The design of belt conveyor system for given problem of conveying raw material is completed.

The results include specifications of belt, motorized pulley, return pulley, carrying troughs and return rollers.

REFERENCES

[1] Rulmeca Corporation, "Conveyor Idler Roller Catalog", pp. 18-264.
[2] Indian Standard: 8598 – 1987.
[3] Indian Standard: 11592 – 2000.
[4] Ed Morris, "Belt conveyors: Some guidelines for selection", CSC publishing, Powder and Bulk Engineering 1994.