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INDUSTRIAL PLANTS

Chapter nineteen:

Belt conveyors – Second part

DOUBLE DEGREE MASTER IN

"PRODUCTION ENGINEERING AND MANAGEMENT"

SEAT OF PORDENONE

UNIVERSITY OF TRIESTE

Sizing of a belt conveyor

The data of departure for the design of a belt conveyor, to which will be associated with the related values in order to present a numerical example, are:

- potentiality requested Q (150 t/h);
- material transported with the appropriate chemical-physical characteristics (coal of wood);
- length of the conveyor in plan L (110 m);
- lifting height overall H (7 m);
- specific weight in the pile γ (of the table 0,5 t/m^3);
- maximum allowable inclination α (of the table 12°).

Sizing of a belt conveyor

It begins with the geometrical sizing of the conveyor:

- verification of the slope the conveyor:

$$\delta = arctg\left(\frac{H}{L}\right) = arctg\left(\frac{7}{110}\right) = 3{,}6°$$

  The slope the conveyor δ is less than the maximum allowable inclination α and then tilting it is verified.

- the actual length the conveyor will:

$$L_T = \sqrt{H^2 + L^2} = \sqrt{7^2 + 110^2} = 110{,}22\ m$$

- for conveyor with slope δ, the capacity is limited:

$$Q_p = p \cdot Q = 0{,}99 \cdot 150 = 148{,}5\ t/h$$

  with p = 0.99 as deduced from the following table.

Sizing of a belt conveyor

Specific weight in the pile of bulk materials and maximum allowable inclination for a belt conveyor			
Material		Specific weight (t/m^3)	Maximum incline
Type	Terms		
Argil	Dry Wet	1,50 2,00	20 – 22
Asphalt	In pieces	1,25	16 – 18
Limestone	In powder	1,50	18 – 20
Lime	In powder	0,50	22 – 23
Beton	In powder	2,20	20 – 22
Kaolin	In powder	0,50	18 – 20
Coal	Of wood Anthracite	0,50 0,75	12 16 – 17
Cement	Dry	1,30	20 -23
Coke	In powder Metallurgic	0,40 0,50	20 18
Chalk	Tout venant	1,30	18 – 20
Gravel	Dry Humid	1,75 2,00	18 – 20 12 – 14
Wheat	-	0,75	15
Iron ore	Size medium and minute Size medium Size minute	1,80 1,70 2,00	18 – 20 18 20 – 22

Sizing of a belt conveyor

Slope of the conveyor δ (°)	Value of p (-)
2	1,00
4	0,99
6	0,98
8	0,97
10	0,95
12	0,93
14	0,91
16	0,89
18	0,85
20	0,81
21	0,78
22	0,76
23	0,73
24	0,71
25	0,68
26	0,66
27	0,64
28	0,61
29	0,59
30	0,56

Sizing of a belt conveyor

The potentiality is obtained from the relationship:

$$Q_p = p \cdot k \cdot \gamma \cdot A \cdot v$$

where:

p = parameter for the reduction of capacity with the slope of the transport

k = constant dependent on units of measurement

γ = specific weight of pile

A = media section of the layer of material on the belt (m^2). The value of A must be calculated in an iterative manner in order to obtain an adequate speed, but within the rated values are calculated from the relationship:

$$v_{nominale} = 0{,}7 \cdot v_{massima}$$

when $v_{massima}$ is obtained from the table**:**

Sizing of a belt conveyor

Width of the belt (mm)	Maximum speed* of the belt for	
	Abrasive material (m/s)	Non abrasive material (m/s)
300	1,50	2,00
400	1,50	2,25
500	2,00	2,25
650	2,50	3,00
800	2,80	3,50
900	3,10	4,00
1000	3,50	4,50
1200	4,00	5,00
……	…..	…..
* often it is assumed equal to about 70% of the maximum value		

v = speed of the conveyor (m/s) which results:

$$v = \frac{Q}{p \cdot k \cdot \gamma \cdot A} = \frac{150}{0{,}99 \cdot 3600 \cdot 0{,}5 \cdot A} = \frac{0{,}084}{A}$$

Sizing of a belt conveyor

To determine the value of the middle section of the layer of material on the belt A, can be used, if it is assumed to use a flat strip, the report:

$$A = \frac{(B+4) \cdot B^2}{110}$$

with B the width of the belt.

If you fixed conservatively a width of first attempt large (B = 1200 mm), we obtain:

$$A = \frac{(B+4) \cdot B^2}{110} = \frac{(1{,}2+4) \cdot 1{,}2^2}{110} = 0{,}068 \ \ m^2$$

consequently the speed will be:

$$v = \frac{0{,}084}{A} = \frac{0{,}084}{0{,}068} = 1{,}24 \ \ m/s$$

For the assumed value of the belt width (1200 mm) and taking into account that the charcoal is an abrasive material, is obtained from the above table a maximum speed of 4 m/s.

Sizing of a belt conveyor

The rated speed is therefore:

$$v_{nominale} = 0,7 \cdot v_{massima} = 0,7 \cdot 4 = 2,8 \;\; m/s$$

The calculated speed is lower than the rated; must be carried out iteratively the reducing the width of the belt. If we set B = 1 m, is obtained by A = 0.042 m^2, which allows to derive a velocity:

$$v = \frac{0,084}{A} = \frac{0,084}{0,045} = 1,87 \;\; m/s$$

From the above table is calculated the value of the maximum speed (3,5 m/s).

The rated speed is therefore:

$$v_{nominale} = 0,7 \cdot v_{massima} = 0,7 \cdot 3,5 = 2,45 \;\; m/s$$

The calculated speed is still lower than the rated.

Sizing of a belt conveyor

If we set B = 0.9 m, we obtain A = 0.036 m^2, which allows you to derive a velocity:

$$v = \frac{0{,}084}{A} = \frac{0{,}084}{0{,}036} = 2{,}33 \ \ m/s$$

From the above table is calculated the value of the maximum speed (3,1 m/s).

The rated speed is therefore:

$$v_{nominale} = 0{,}7 \cdot v_{massima} = 0{,}7 \cdot 3{,}1 = 2{,}17 \ \ m/s$$

The calculated speed is now higher than the nominal; arises in conclusion, the width of the belt equal to B = 0.9 m.

Sizing of a belt conveyor

Subsequently, is go to determine the resistances to motion the conveyor, which are the following:

a) **resistance to advancement in vacuum R_1**, that is in the absence of material related to the rolling friction of the mass movement of the conveyor (belt, rollers, drums, referrals etc.)

This resistance can be evaluated via the relation:

$$R_1 = f \cdot q_s \cdot L'$$

where:

f = coefficient of friction of the rolling elements (rollers). In particular, one can have the following values: carrier roller bearings with maintenance standard: 0.03, roller bearing with poor maintenance: 0.05 (value considered in this example), belt without cover rubber strip of shiny metal surfaces: 0.30, belt with rubber cover strip of shiny metal surfaces: 0.50

q_s = weight of moving parts of the conveyor in relation to the length of the conveyor, shown in the table:

Sizing of a belt conveyor

Subsequently, is go to determine the resistances to motion the conveyor, which are the following:

a) resistance to advancement in vacuum R_1

Lenght of the belt B (mm)	Weight of moving parts (N/m)
300	200
400	235
500	310
650	370
800	540
900	638
1000	735
1200	880
……	……

Sizing of a belt conveyor

Subsequently, is go to determine the resistances to motion the conveyor, which are the following:

a) resistance to advancement in vacuum R_1

To assess the total resistance R_1, the calculation will be made by increasing the interaxis of the conveyor of a length fictional, which takes account of any friction between the moving parts and the fixed and is:

L' = L + (60 – 0,2 · L) = 110 + (60 – 0,2 · 110) = 148 m

where:

L = conveyor length measured between the axes of the drum motor and drum driven end

The total resistance to motion in the absence of load that is:

$$R_1 = 0{,}05 \cdot 638 \cdot 148 = 4721 \ N$$

The effort R_1 is composed of a resistance in the upper tract of the belt conveyor and a resistance in the lower tract. The first resistance is greater than the second in that the spacing of the rollers in the upper section is less than the lower portion.

Sizing of a belt conveyor

Subsequently, is go to determine the resistances to motion the conveyor, which are the following:

a) resistance to advancement in vacuum R_1

As a first approximation the R1 can be considered due for 2/3 to upper and 1/3 of the lower tract, so there will be:

$$R_{1s} = \frac{2}{3} \cdot 4721 = 3147 \quad N$$

$$R_{1i} = \frac{1}{3} \cdot 4721 = 1574 \quad N$$

Sizing of a belt conveyor

Subsequently, is go to determine the resistances to motion the conveyor, which are the following:

b) resistance induced by the presence of the material

It determines the weight of the load length-related q_m expressed by the relation:

$$\mathbf{q_m = A \cdot \gamma = 0,036 \cdot 0,5 \cdot 10000 = 180\ N/m}$$

The frictional resistance for the transport of the material is:

$$R_2 = f \cdot q_m \cdot L_m$$

where:

f = coefficient of friction of the rolling elements (rollers)

L_m = length of the load of the conveyor belt which is fictitiously equal to:

$$\mathbf{L_m = L + (60 - 0,2 \cdot L) = 110 + (60 - 0,2 \cdot 110) = 148\ m}$$

$$R_2 = 0,05 \cdot 180 \cdot 148 = 1332\ \ N$$

Sizing of a belt conveyor

Subsequently, is go to determine the resistances to motion the conveyor, which are the following:

c) resistance for overcome with the material the difference in level H between the points of loading and unloading

The report is in this case equal to:

$$R_3 = q_m \cdot H = 180 \cdot 7 = 1260 \;\; N$$

d) resistance due to possible arresters fixed R_4 or mobile R_5, whose effort can be calculated from the relationship

$$R_4 = a \cdot q_m = 0 \;\; N \qquad\qquad R_5 = b \cdot q_m = 0 \;\; N$$

being a and b two constants, function of the width of the tape, and whose values are detectable from the table

Sizing of a belt conveyor

Subsequently, is go to determine the resistances to motion the conveyor, which are the following:

d) resistance due to possible arresters fixed R4 or mobile R5, whose effort can be calculated from the relationship

Lenght of the belt (mm)	a	b
300	0,080	30
400	0,085	35
500	0,090	45
600	0,095	50
700	0,110	60
800	0,115	75
900	0,120	90
1000	0,125	100
1100	0,130	110
1200	0,140	120

Since in this case there are no arresters fixed or mobile, the value of R_4 e R_5 are null.

Sizing of a belt conveyor

The total resistance at the periphery of the driving pulley is given by the sum of the resistances:

$$R = \sum_{i=1}^{5} R_i = 4721 + 1332 + 1260 + 0 + 0 = 7313 \ \ N$$

Determine the forward speed of the tape or of the material and the resistance of the bike, it is possible to determine the power transferred to the feed system that results from the relationship:

$$P = \frac{R \cdot v}{1000} = \frac{7313 \cdot 2{,}17}{1000} = 15{,}87 \ \ kW$$

Assuming that the system for coupling the electric motor-driving pulley, resulting in the presence of a reduction gear and to the performance of the electric motor, it is possible to have an efficiency of the motor assembly η of 0,81, is obtained by the minimum power absorbed by the electric motor equal to:

$$P_{mot,\min} = \frac{P}{\eta} = \frac{15{,}87}{0{,}81} = 19{,}6 \ \ kW$$

Sizing of a belt conveyor

It will be convenient to oversize the electric motor, causing the power absorbed under normal conditions represent 75% of the power delivered by the motor itself. So is the relationship:

$$P_{mot} = P_{mot,\min} \cdot \frac{100}{75} = 19{,}6 \cdot \frac{100}{75} = 26{,}1 \ kW$$

For a system three-phase with mains voltage V of 380 V, is obtained the power to the switch that is:

$$P_{mot} = V \cdot I \cdot \cos\varphi \cdot \sqrt{3}$$

so that we can calculate the current that the switch must support that is:

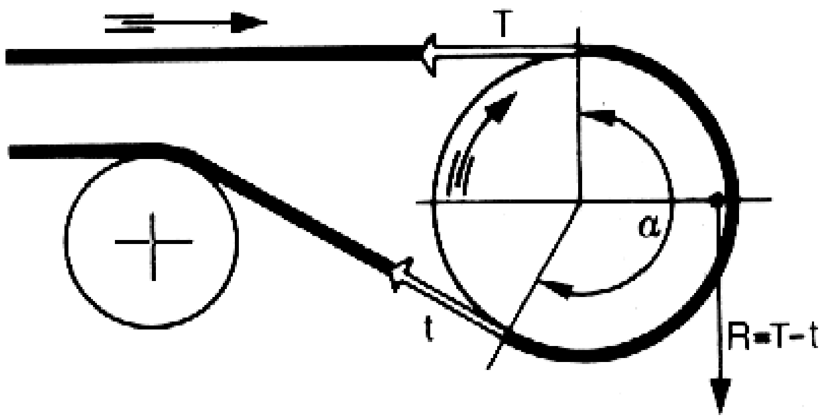
$$I = \frac{P_{mot}}{\sqrt{3} \cdot \cos\varphi \cdot V} = \frac{26100}{\sqrt{3} \cdot 0{,}8 \cdot 380} = 50 \ A$$

Are determined according to the tension of the belt.

Sizing of a belt conveyor

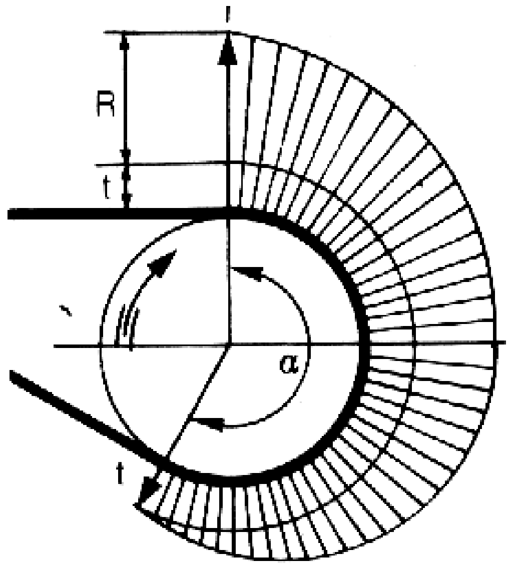
The peripheral effort requires a torque R given by the difference of the tensions T (tense tract) and t (less tense tract)**:**

$$\mathbf{R = T - t}$$



Sizing of a belt conveyor

The figure shows the trend of the exponential type of the tensions in the tape passing from the point of maximum stress to that of minimum:



Sizing of a belt conveyor

The values of T and t are also bound by the limit condition of adhesion between belt and pulley:

$$\frac{T}{t} = e^{\alpha\mu}$$

where:

α = winding angle;

μ = coefficient of friction between the tape and the motor drum.

Known the total effort R and the fixed ratio T/t, can be determined:

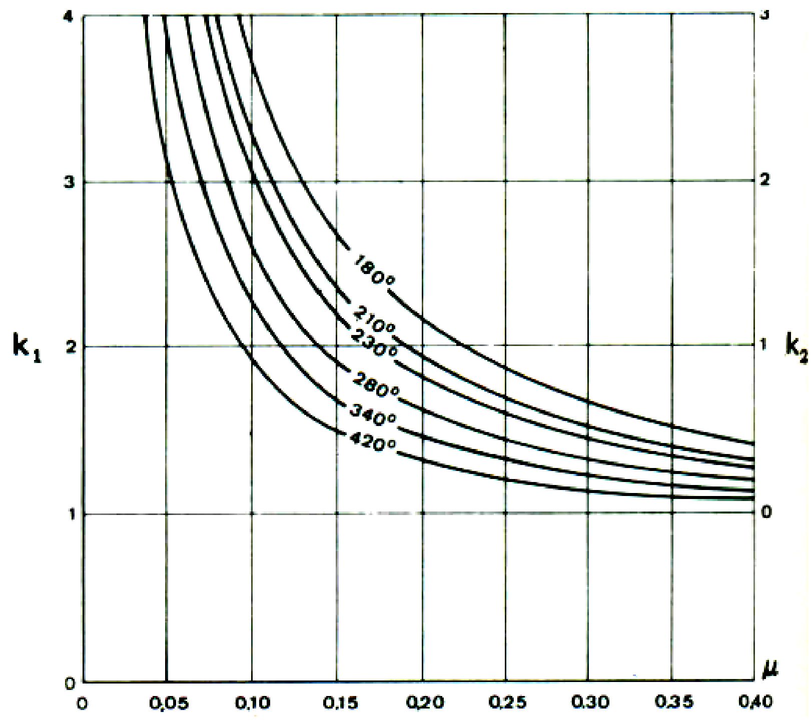
$$\begin{cases} T = \left(1 + \dfrac{1}{e^{\alpha\mu} - 1}\right) \cdot R = k_1 \cdot R \\ t = \dfrac{1}{e^{\alpha\mu} - 1} \cdot R = k_2 \cdot R \end{cases}$$

Sizing of a belt conveyor

The values of k_1 and k_2 as a function of the angle of winding α and the coefficient of friction between the belt and the motor drum μ, are shown in the figure below.

Chosen $\alpha = \pi$, that is the diameter of the driving pulley is equal to that of the return pulley, and μ = 0,30, typical value for the turnbuckles to counterweight, is obtained:

$$k_1 = 1{,}64 \quad \text{and} \quad k_2 = 0{,}64$$



Sizing of a belt conveyor

Ultimately we obtain:

$$\begin{cases} T = k_1 \cdot R = 1{,}64 \cdot 7313 = 11993 \;\; N \\ t = k_2 \cdot R = 0{,}64 \cdot 7313 = 4680 \;\; N \end{cases}$$

The tension t must be such that the point less tense of the conveyor belt is still has a voltage t_{min}, sufficient to avoid an unacceptable inflection of the tape between two successive rollers (hypothesis of maximum load).

In practice:

$$t_{min} = 50 \cdot 9{,}81 \cdot n \cdot B$$

where:

n = number of plies that forming the belt;

B = width of the belt (m).

Sizing of a belt conveyor

The number of the plies has not yet been determined, but assuming to consider the maximum value of the same for that width of the belt B (see the table below n = 9), it is determined:

$$t_{min} = 50 \cdot 9{,}81 \cdot 9 \cdot 0{,}9 = 3973 \text{ N}$$

tension lower than the value t determined previously and therefore acceptable

Width of the belt (mm)	Number of canvases	
	Minimum	Maximum (for concave belts)
300	3	4
400	3	4
500	3	5
600	3	6
700	3	7
800	4	8
900	4	9
1000	4	10
1100	5	11
1200	5	12
1300	5	12

Sizing of a belt conveyor

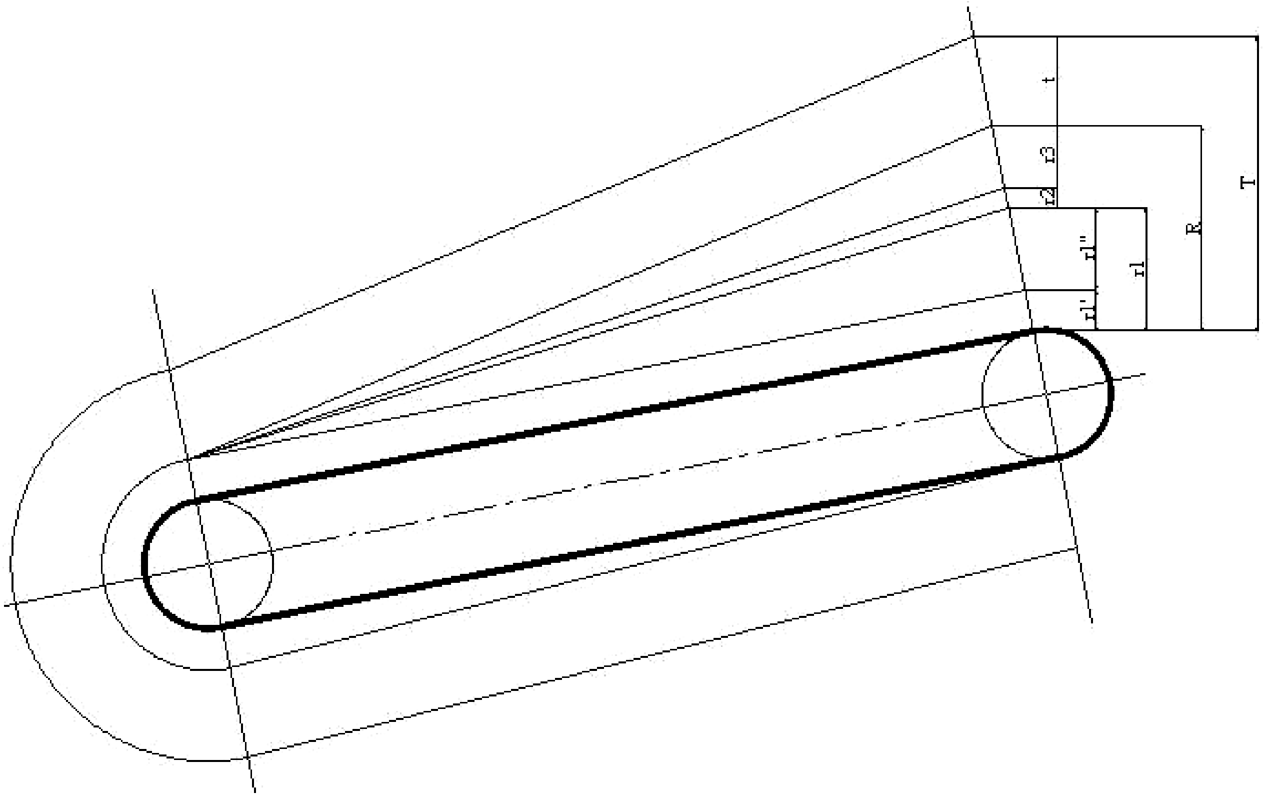
As we have seen previously, the resistance due to friction of the mass in motion the conveyor (belt, rollers, drums, references etc.) R_1 in the no-load operation, is distributed in the upper and lower R_{1s} R_{1i}, in first approximation, for 2/3 to upper tract and the remaining 1/3 in the lower tract.

$$R_{1s} = \frac{2}{3} \cdot 4721 = 3147 \quad N \qquad\qquad R_{1i} = \frac{1}{3} \cdot 4721 = 1574 \quad N$$

This given is significant to make then the verification of the belt itself.

Sizing of a belt conveyor

The distribution of tensions is shown in the graph.



Sizing of a belt conveyor

It then determines the number of canvases of the belt and you verification the same.

Note the maximum tension T, we can calculate the number of canvases forming the nucleus n (otherwise it calculates the thickness if the tape is not at plies):

$$n = \frac{T}{K \cdot B}$$

where:

K = resistance of unit length of a canvas (values between 45-70 N/cm width and canvas). Depending on the fabric of the canvas may collect the following values of K function of the number of the plies

Quality	Number of canvases				
	3	4	5	6	7
L	54,0	51,5	49,0	48,5	44,0
M	63,0	60,0	57,0	54,0	51,0
P	67,5	64,0	61,0	58,0	55,0

B = width of the belt (cm).

Sizing of a belt conveyor

Place the quality of the plies L and a fixed value of K = 50 N/cm width and canvas, is obtained:

$$n = \frac{11993}{50 \cdot 90} = 2{,}66 \ \ canvases$$

If you report at 4 plies, this is also the minimum number of plies for this type of belt, because it is known that n must be at least that value because it is not too rigid and it can bend around the pulleys and that the tension t is greater or equal at t_{min}.

The tension of breaking of the canvas for this type of tape is:

$$T_R = K \cdot B \cdot n = 51{,}5 \cdot 90 \cdot 4 = 18540 \ \ N$$

which is still 35% higher than that of project.

Sizing of a belt conveyor

With regard to the diameter of the pulleys, the table below provides the minimum values of the diameters for the driving pulley and that of reference in function of the number of plies and the type of fabric of the same.

From the table, it is noted that for ribbons of type L with 4 plies, it requires a diameter of the driving pulley of 450 mm.

Since it was chosen $\alpha = \pi$, also the return pulley (moved) will have the same diameter of the driving pulley.

Number of canvanses of the belt	Type tissue L		Type tissue M		Type tissue P	
	Diameter of driving pulley (mm)	Diameter of return pulley (mm)	Diameter of driving pulley (mm)	Diameter of return pulley (mm)	Diameter of driving pulley (mm)	Diameter of return pulley (mm)
3	400	300	400	300	450	400
4	450	375	500	400	600	500
5	600	450	650	500	750	600
6	650	550	750	600	900	750
7	750	600	850	700	1050	850
8	800	650	1000	800	1200	1000
9	1000	750	1100	900	1400	1100

Sizing of a belt conveyor

From the table below, you can deduce the interax between the rollers:

- interax between the upper rollers = 1,10 m;
- interax between the lower rollers = 2,5 m (2,50-6,00 m for any width of the belt and for any load).

The guide rollers, both in the charge part that of the return, should be installed approximately 15 m from each terminal pulley or return pulley or approximately 30 m from each other.

Width of the belt (m)	Interax between the upper rollers (m) for material bulk density (t/m^3)			
	0,8	1,2	1,6	2,4
0,40	1,50	1,40	1,40	1,30
0,50	1,40	1,30	1,30	1,20
0,60	1,30	1,30	1,20	1,20
0,80	1,30	1,20	1,20	1,10
1,00	1,10	1,10	1,00	1,00
1,20	1,10	1,10	1,00	1,00

Sizing of a belt conveyor

We can now calculate the length of the belt L_n, that wraps around the pulleys.

There is the relation:

$$L_n = 2 \cdot L + \frac{(D \cdot \alpha_m + d \cdot \alpha_r)}{2}$$

where:

L = transport length (distance between the two pulleys);

D = diameter of the driving pulley;

d = diameter of the return pulley;

α_m = winding angle of the driving pulley;

α_r = winding angle of the return pulley.

Sizing of a belt conveyor

The length of the belt is therefore:

$$L_n = 2 \cdot 110 + \frac{(0{,}45 \cdot \pi + 0{,}45 \cdot \pi)}{2} = 221{,}4 \ m$$

It is also assumed:

- width of the pulleys 950 mm;
- distance between the edge of the belt and the fixed parts 75 mm;
- diameter of rollers 150 mm.

To choose the type of transmission is necessary to know the number of revolutions of the driving pulley n_M and establish that of the electric motor.

The speed of rotation of the driving pulley is given by:

$$n_M = \frac{60 \cdot \varpi}{2 \cdot \pi} = \frac{60 \cdot v}{2 \cdot D} = \frac{60 \cdot 2{,}17}{2 \cdot 0{,}45} = 144{,}6 \, revolutions / \min ute$$

where:

v = speed of the belt (m/s);

D = diameter of the driving pulley (m).

Sizing of a belt conveyor

Assuming you take a three phase induction motor at 4 pole and with speed of synchronous n' = 1500 revolutions/minute and operating with a sliding s = 5%, will require a reduction gear with global transmission ratio equal to:

$$\tau = (1-s)\cdot\frac{n'}{n_M} = (1-0{,}05)\cdot\frac{1500}{144{,}6} = 9{,}85$$

It can be achieved with an ordinary gear train of 2 or 3 trains of reduction gears.

With regard to the dimensioning of the counterweight, is fixed attention to the load situation of the pulley that, neglecting the friction of the pin, is located in the load condition detected in the previous figure where it is identified the qualitative behavior of the voltages along the conveyor belt.

The mass of the counterweight must be:

$$F = 2\cdot(t - R_1') = 2\cdot\left(t + \frac{R_1}{3}\right) = 2\cdot\left(4680 + \frac{4721}{3}\right) = 12507 \quad N$$

Belt conveyors special

The belt conveyors can overcome slopes which depend on the chemical-physical characteristics of the material (coefficient of friction, particle size etc.). For steeper slopes, even if they are allowed of the lower flow rates and lower speed of the belt, are taken of the particular devices:

a) **belt conveyors with projections**

On the top cover of the tape are shown of the projections (transverse or V), which allow to keep the material that tends to go back. These projections can then be printed or applied directly on the tape. To avoid that there are shock between the projections and the lower rollers of support, you put the belt on a pairs of rollers, which support the same along the side edges

Belt conveyors special

The belt conveyors can overcome slopes which depend on the chemical-physical characteristics of the material (coefficient of friction, particle size etc.). For steeper slopes, even if they are allowed of the lower flow rates and lower speed of the belt, are taken of the particular devices:

b) belt conveyor with cross bars and side rails

They are used in aspects of the side rails and transverse divisions in case you need to climb slopes between 45° and 70° or rotate the belt of concave and convex corners

Belt conveyors special

The belt conveyors can overcome slopes which depend on the chemical-physical characteristics of the material (coefficient of friction, particle size etc.). For steeper slopes, even if they are allowed of the lower flow rates and lower speed of the belt, are taken of the particular devices:

c) mobile belt conveyors

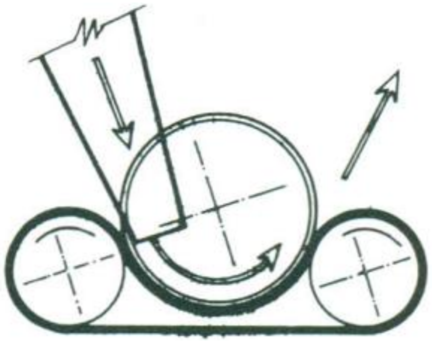
Serve for load of the vehicle or for the accumulation of materials in warehouses or stores, or for services in the pipeline. There are a few meters long and equipped with a transport capacity low, are mounted on wheels to allow easy movement

Belt conveyors special

The belt conveyors can overcome slopes which depend on the chemical-physical characteristics of the material (coefficient of friction, particle size etc.). For steeper slopes, even if they are allowed of the lower flow rates and lower speed of the belt, are taken of the particular devices:

d) belts launches-ground

Are devices used to launch the materials in powder or fine grade at a certain distance from the point of discharge (drive pulley of the belt conveyor). The material is loaded at the beginning of the concave curve of the tape, obtained from two pulleys which act on the edges of the tape. When the material arrives on the driving pulley which is equipped with a speed as to leave the tape and to continue according to a suitable trajectory which allows to load vehicles, of the piles form, fill deposits etc.



Belt conveyors special

The belt conveyors can overcome slopes which depend on the chemical-physical characteristics of the material (coefficient of friction, particle size etc.). For steeper slopes, even if they are allowed of the lower flow rates and lower speed of the belt, are taken of the particular devices:

e) magnetic separators

Used when the material shows the ferrous parts that need to be extracted. Installing a magnetic separator in the vicinity of the head of the driving pulley of the conveyor or in a position perpendicular to the conveyor, or by installing the magnetic separators within the driving pulley the conveyor

Belt conveyors special

Other types of magnetic separator