PDHonline Course M360 (1 PDH)

Chain Conveyors - Practical Calculations

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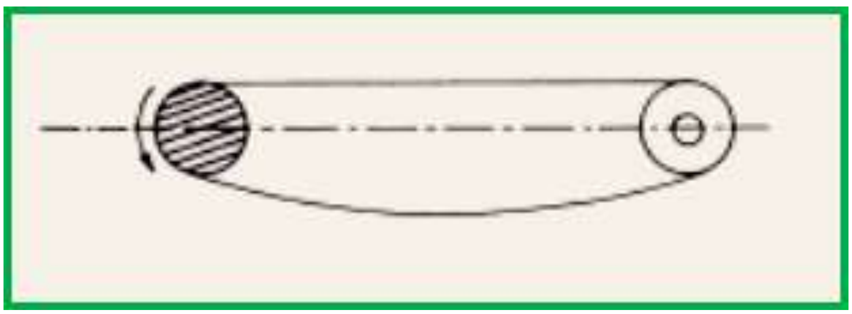
CHAIN & APRON CONVEYORS

1. INTRODUCTION:

Roller Chain Conveyors or Apron Chain Conveyors are used to transfer heavy bulk materials from one point to another. This manual for practical application indicates the chain conveyor basic calculations for Bulk Materials in the metric and imperial system. The main function is informative for both experienced professionals and beginners interested in knowing the dynamics of this segment of Material Handling.

a. Arrangement: Drive chains are ideally installed with the shaft in the horizontal position, as shown below:



b. Position of Sprockets: The sprockets should be matched in pairs. Since the tail shaft is an idling shaft, key it to only one sprocket. In this way the sprocket can position itself if uneven wear takes place in the chain strands. The two shafts should be parallel and the sprockets should be firmly installed. Use a straight edge to check that the two sprockets are installed along the same horizontal level. This is illustrated in Figure 1 and 2 below:

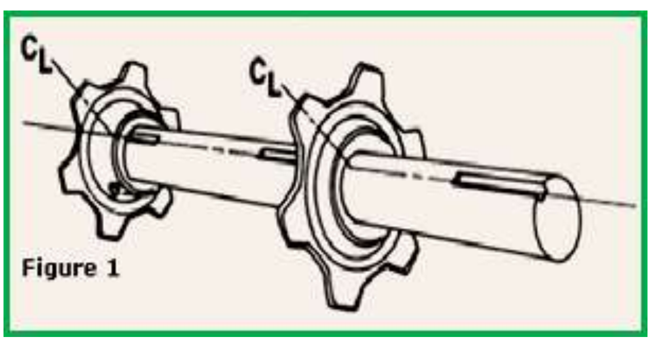


Figure 1

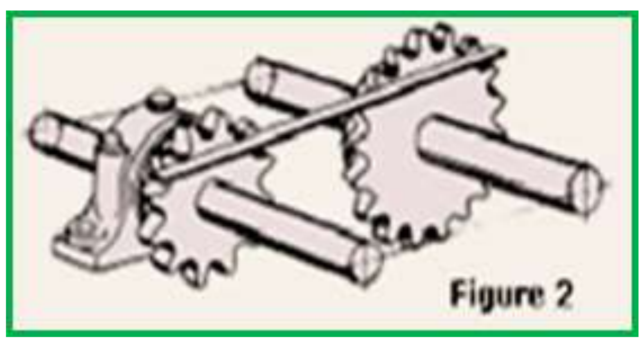


Figure 2

c. Chain Conveyor Speed: Commonly the Chain Conveyor speed is dictated by how it is loaded and unloaded and what is done to the load during conveying. The table below shows the basic conveyors and their typical operating speeds.

CONVEYOR	SPEED (fpm)
Continuous Bucket Elevator	75 to 150
Centrifugal Bucket Elevator	200 to 300
Slat or flat top Conveyor	50 to 150
Assembly line Conveyor	5 to 15
Drag and Scraper Conveyors	50 to 100
Apron Conveyors	10 to 60

2. APRON CHAIN CONVEYORS:

Apron feeders are used in the mining industry for the transportation of heavy and lumpy materials. These conveyors are designed for the hardest conditions of exploitation to feed the crushers at quarry and storage bins. Apron feeders have capacities up to **6000 t/h** and are able to transport materials with maximum lump size up to **2000 mm**. The large size of material lumps is the cause for the increase of the width of the aprons and the height of the skirts.

The presence of **fixed skirts** causes additional resistances due to **skirt friction**. The presence of receiving hopper causes additional resistance due to the weight and pressure of the material to be fed. The hard conditions of exploitation and the great starting resistances are the main causes for the introduction of several coefficients to increase the motor driving power.

a. Calculations: The basic formulae for Apron Chain Feeders calculation are given only for references, since that each manufacturing company has its own methodology for calculation.

b. Velocity, Width and Height of Skirts: As the transported material is lumpy, its maximum lump size will determine the apron **width B**, in meters:

B = 0.0017 x a (max.) + 0.2 =

Considering the following data:

a_{max} [mm]	315	400	500	650	800	1000	1250	1600
B [m]	0,8	1	1,25	1,4	1,6	1,8	2	2,5
h [m]	0,5	0,6	0,8	1	1,1	1,2	1,3	1,8

The formula for the determination of the height of the **skirts "h"** is given h for apron conveyors, as:

h = 0.65 x B =

When **width B** and height of the **skirts "h"**, in meters, are determined, the apron **speed "v"** is determined by the known formula for the capacity:

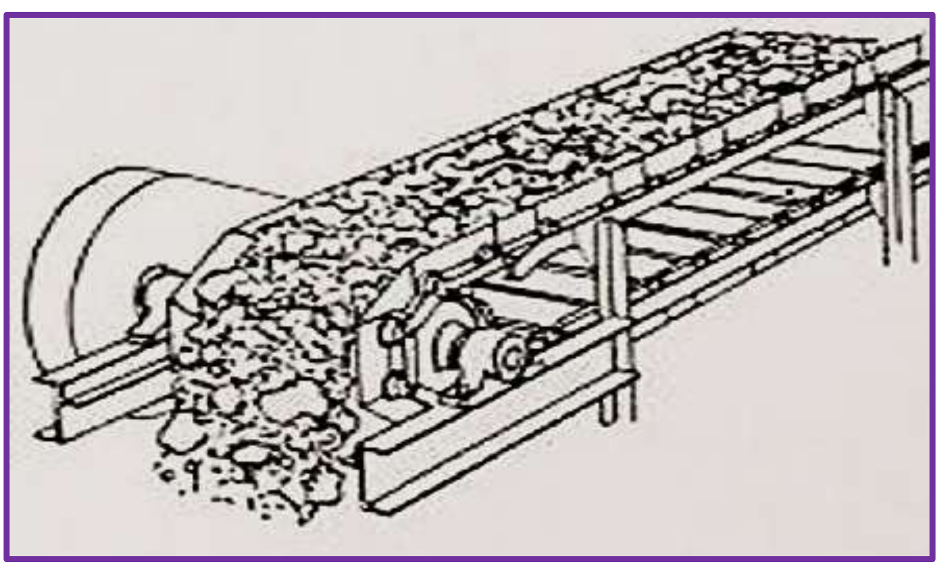
$$v = \frac{Qh}{3600 \times B \times h \times \rho \times \psi \times c} = (m/s)$$

Where:

Qh = Capacity in t/h;
ρ = Density of the transported material in t/m³ (t/ft³);
ψ = Extraction efficiency factor = 0.75;
c = $\frac{100 - \beta}{100}$ - inclination factor (β - angle of inclination).

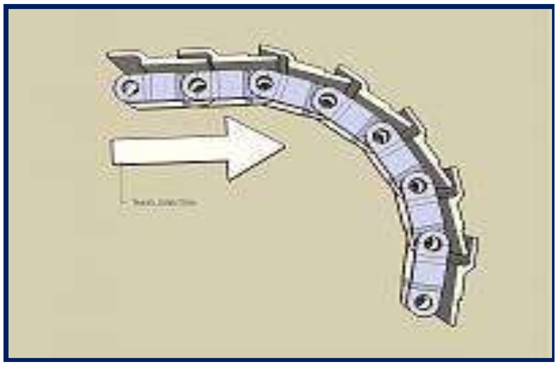
The coefficient **"c",** must be taken into account, when the feeding system is inclined **(β = 15° - 25°)**. The reason for the inclination is the facilitation of **truck discharge** and the protection of the equipment when the material will fall directly on it. Speed is limited to **0.25 m/s (0.82 ft/s)**, and in some cases to **0.4 m/s (1.3 ft/s)**. The reasons for the limitation are the great dynamic loads in the track chains and the high abrasion wear of the aprons.

If the calculated speed "**v**" is greater than the limit speed for aprons, the skirt height **"h"** must be increased. The drives allow variation of the speed to match, which is **v = 0.03 m/s – 0.16 m/s (0.1 – 0.5 ft/s)**. For different capacities, can be used **variable speed DC, AC** and **hydraulic motors**.

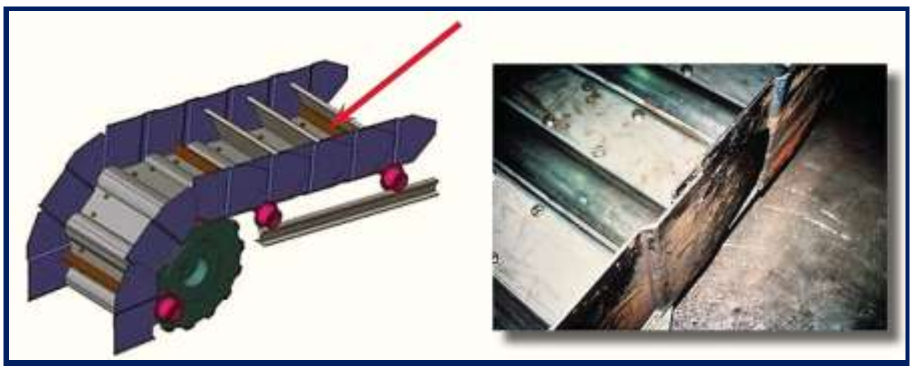


1. Apron Chain Types and Rollers:

Apron feeders use heavy duty **crawler tractor chains** (Caterpillar tractor type), commonly sized to suit the application. The chain links are forged for increased load capacity. The apron plates are bolted on flat top of the chain links. Pins and bushes are hardened on the wearing surface. The carrying rollers are spaced to eliminate the sag, mounted on support frames to permit removal for replacements.

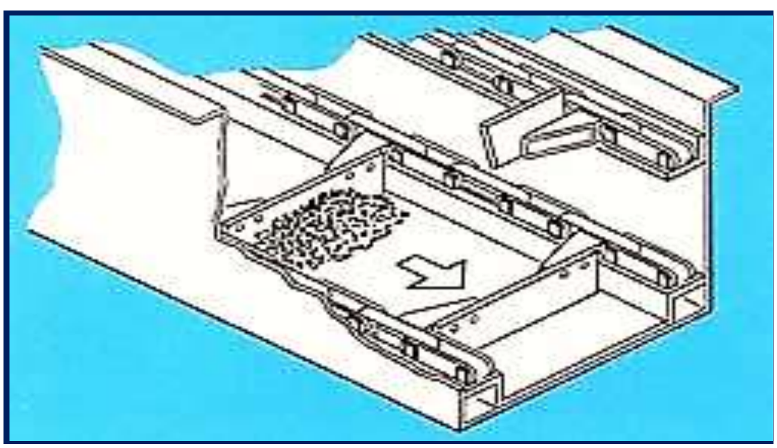


Special design and exclusive metal to metal allows continuous pan contact through articulation minimizes spillage and leakage, as indicated below:



2. Drag and Flight Conveyors:

Drag conveyors are used where multiple loading or discharge points are required and a totally enclosed conveyor is needed for dust containment, capable of handling fine materials ranging from dust to **6 inch (150 mm)** lumps, where capacity requirements are high, **200 - 400 TPH**. Drag conveyors are used when the material is somewhat fluid, such as TSP (fertilizers), raw meal, and finish cement.



3. EASY CALCULATIONS:

1) Chain conveyor or apron chain conveyor calculation system. The **load tensions** are calculated as indicated below:

T = Fs + Fi + Fk (Kgf) (lbf) =

- **Fs** = [(Qt x L) + (Pch x L)] x f =
- **Fi** = $\dfrac{\text{Pch x L}}{2}$ x f1 =
- **Fk** = (Qt + Pch) x L1 x sen α x f2 =

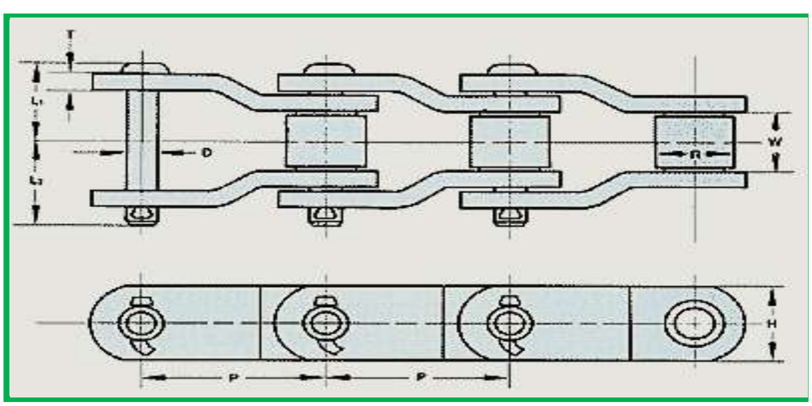
Where:

T = Total chain force or total work chain tension – (kgf) (lbf);
Fs = Upper chain tension – (kgf) (lbf);
Fi = Down chain tension – (kgf) (lbf);
Fk = Lift chain tension – (kgf) (lbf);
Q = Conveyor total load - (t/h) (tph);
Qt = Conveyed material weight – (kg/m) (lb/ft);
L = Total conveyor direct length (including inclined/declined) - (m) (ft);
L1 = Conveyor horizontal direct length – (m) (ft);
L2 = Conveyor slope (inclined / declined) extension direct length – (m) (ft);
Pch = Total chain weight (**see manufacturers tables** according to chain types);
N = Driving power (kW) - (HP).

f = Upper chain friction factor – 0.25 ~ 0.35;
f1 = Down chain friction factor – 0.10 ~ 0.15;
f2 = Lift chain friction factor – 0.25 ~ 0.35;
v = Chain conveyor speed – (m/s) - (fpm);
D = Driving sprocket diameter – (mm) - (in);
α = Conveyor slope angle;
δ = Bulk density of conveyed material – (kg/m^3) - (lb/ft^3).

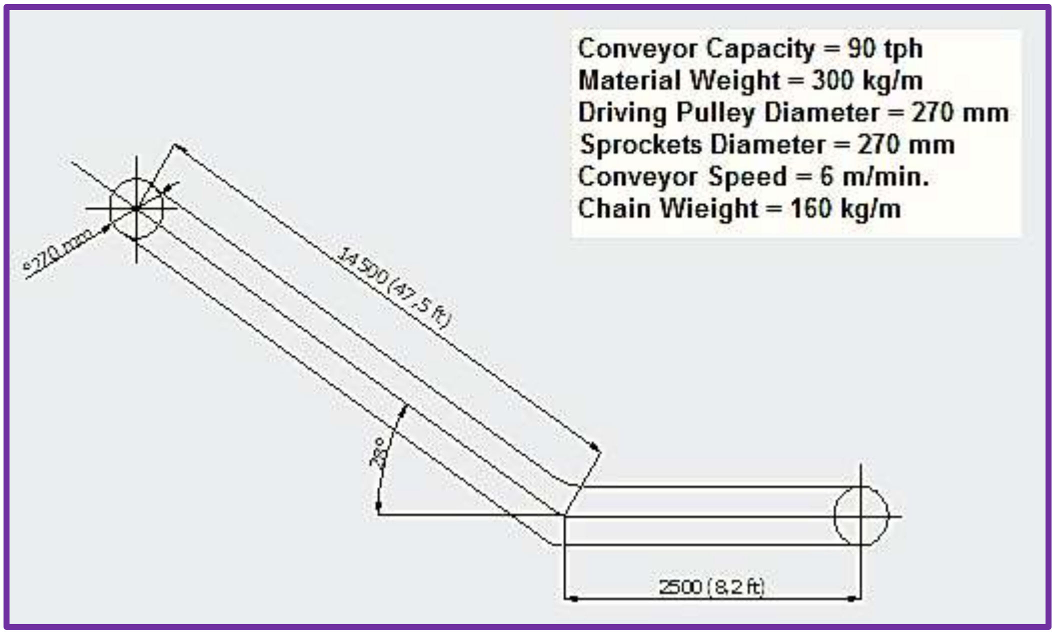
2) To calculate the driving power (**CV or HP**), use the following formulas:

N = $\dfrac{\mathbf{T \times v\ (m/s)}}{\mathbf{75}}$ = (metric) and $\dfrac{\mathbf{T \times v\ (fpm)}}{\mathbf{33000}}$ = (imperial).



4. PRACTICAL EXAMPLE:

Calculate the driving power of a **Drag Roller Chain Conveyor,** commonly used in Sugar Plants considering the following sketch below:



Where:

Q - Chain conveyor capacity = 90 tph;
δ - Sugar cane bulk density = 900 kg/m³ - (56 lb/ft³);
v – Conveyor speed = 5 m/min (0.083 m/s) – (16.3 fpm);
D - Driving sprocket diameter = 270 mm – (10.6 in);
d – Driving pulley on driving shaft = 290 mm – (11.4 in);
Pch -Total drag chain weight = 160 kg/m (both sides) – (107.5 lb/ft);
L1 - Conveyor horizontal direct length = 2.5 m – (8.2 ft);
L2 = Conveyor slope (inclined) direct length = 14.5 m – (47.5 ft);
α = Conveyor slope angle = 28º.

Solution:

a. Calculation According to Material Flow:

$\frac{kg/h}{m/h} = \mathbf{kg/m}$ or $\frac{lb/h}{ft/h} = \mathbf{lb/ft}$

Q = **90 tph** = **90,000 kg/h (198,450 lb/h) =**
v = **5 m/min.** = **5 x 60 = 300 m/h (984 ft/h) =**

Qt = $\frac{90{,}000 \text{ kg/h}}{300 \text{ m/h}}$ = $\boxed{\mathbf{300\ kg/m}}$ **–** Qt = $\frac{198{,}450 \text{ lb/h}}{984 \text{ ft/h}}$ = $\boxed{\mathbf{202\ lb/ft}}$

L = L1 + L2 = $\boxed{\mathbf{17.0\ m}}$ **(55.7 ft)**

a) Fs = (Qt x L) + (Pch x L) x f =

Fs = (300 x 17.0) + (160 x 17.0) x 0.25 = $\boxed{\textbf{1955 kgf}}$ **(4310 lbf)**

b) Fi = $\frac{Pch \times L}{2} \times f1 = \frac{160 \times 17.0}{2} \times 0.15 =$

Fi = $\frac{2720}{2} \times 0.15 =$ $\boxed{\textbf{204 kgf}}$ **(450 lbf)**

c) Fk = (Qt + Pch) x L2 x sin 28º x f2 =

Fk = (300 + 160) x 14.5 x sin 28º x 0.35 = $\boxed{\textbf{1096 kgf}}$ **(2416 lbf)**

d) T = Fs + Fi + Fk = 1955 + 204 + 1096 =

T = $\boxed{\textbf{3255 kgf}}$ **(7177 lb.ft)**

$$N = \frac{T \times v}{75} = \frac{3255 \times 0.083}{75} = 3.6 \sim \boxed{\textbf{5.0 CV}}$$

Or:

$$N = \frac{T \times v}{33000} = \frac{7177 \times 16.3}{33000} = 3.5 \sim \boxed{\textbf{5.0 HP}}$$

b. Calculation According to Tsubaki Company:

T = [(Qt + 2.1.Pch) x f1 x L1] + [(Qt + Pch) x (f1 x L2 x cos α + L2 x sin α) + [1.1.Pch (f1 x L2 x cos α – L2 x sin α)] = (kgf) (lbf)

Using the data above, calculate the tension using the **Tsubaki company formula**:

T = [(300 + 2.1x 160) x 0.15 x 2.5] + [(300 +160) x (0.15 x 14.5 x cos 28º + 14.5 x sin 28º)] + [1.1 x 160 (0.15 x 14.5 x cos 28º - 14.5 x sin 28º)] =

T = $\boxed{\textbf{4254 kgf}}$ **(9380 lbf)**

Metric System = N = $\frac{T \times v}{75} = \frac{4254 \times 0.083}{75} = 4.7 \sim \boxed{\textbf{5.0 CV}}$

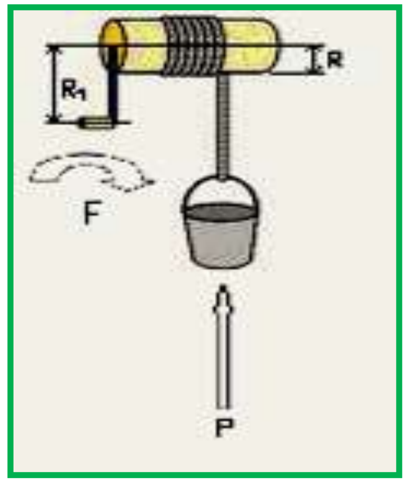
US System = N = $\frac{T \times v\ldots}{33{,}000} = \frac{9380 \times 16.3}{33{,}000} = 4.6 \sim \boxed{\textbf{5.0 HP}}$

c. Calculation According to Winch Torque:

According to applied mechanics the torque calculation to **revolve the driving chain conveyor pulley** just like the windlass or a winch arm to **pull a bucket** is:

F x R1 = P x R =

Where:



P = Conveyor chain force to pull the load, kgf;

R = Driving sprocket radius, m;

F = Pulley peripheral force on driving shaft, m;

R1 = Driving pulley radius, m.

Calculate the **driving chain conveyor power**, using the data above.

F x R1 = P x R =

a) P is the force to carry up the sugar cane plus the chain weight, as we calculated before:

P = Fs + Fi + Fk = 1955 + 204 +1096 =

$\mathbf{P} = \boxed{\mathbf{3255\ kgf}}$ **(7177 lbf)**

Or,

$\mathbf{P} = \boxed{\mathbf{4254}}$ **(9380 lbf)** - according to Tsubaki formula.

b) The conveyor data above indicate the **sprockets diameters**, **D = 270 mm**, then: **R = 0,135 (5.3 in).**

c) The diameter of the driving pulley on **driving shaft** is, **d = 290 mm**, then: **R1 = 0,145 (5.7 in).**

We need to find the force **F** to move the driving shaft, so:

$$\frac{P}{F} = \frac{R1}{R} = \frac{3255}{F} = \frac{0.145}{0.135} = F = \boxed{3030\ \text{kgf}} \text{ and, } \frac{7177}{F} = \frac{5.7}{5.3} = \boxed{6673\ \text{lbf}}$$

$$N = \frac{F \times v}{75} = \frac{3030 \times 0.083}{75} = 3.35 \sim \boxed{5.0\ \text{CV}}$$

$$N = \frac{F \times v}{33{,}000} = \frac{6673 \times 16.3}{33{,}000} = 3.3 \sim \boxed{5.0\ \text{HP}}$$

5. CHAIN CONVEYORS OR APRON CONVEYORS SUMMARY:

Chain conveyors or also called apron conveyors are commonly used in siderurgy and mining industries to transport heavy minerals The manufacturing industry also use widely chain conveyors to carry unit loads, pallets, grid boxes and general industrial containers. These conveyors can be single or **double chain strand or Caterpillar** type chains. Single chain conveyors are generally easy to install and have very minimum maintenance for users.

Many industry sectors use chain conveyor technology in their production lines. The automotive industry commonly uses chain conveyor systems to convey car parts through paint plants. Chain conveyors also have widespread use in the white and brown goods, metal finishing and distribution industries.

Chain conveyors are also used in the painting and coating industry, ceramics, thermal treatment of metals, feed and discharge systems of boilers. In automatic painting systems the products are attached to an above head chain conveyor, keeping products off of the floor allows for higher productivity levels.

References:

OBS.: This is a didactic and professional handbook. It´s highly recommended downloading and printing the course content for your study, before answering the quiz questions.

Sugar Cane Handling and Process Equipment, Dedini, 1st Edition, 1975

Tsubaki Manufacturer, Chain Conveyor Calculations

Grinding Manual, Technical Publication, Faço/Allis-Chalmers, 4th Edition, 1985