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*D*esign of Slat Conveyor for Bagasse Handling in Chemical Industry

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Abstract:
A conveyor system is a common piece of material handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Bagasse is the fibrous matter that remains after sugarcane are crushed to extract their juice. It is currently used as a bio-fuel and in the manufacture of pulp and building materials.

1. Introduction

Modern civilization requires handling of bulk materials in huge quantity. Our present civilization aims at producing innumerable items for utility and comfort of human race. All these items are produced from raw material from our unique planet with appropriate / modification.

To cote some examples, we need huge quantity of cement, which is made from mine materials. We need steel to make simple kitchen knife to steamers, which requires movement of huge quantity of iron ore at national as well as global levels. Every man needs electric power at his disposal, which demands generation of electric power on mega scale. Hence requirement for movement of huge quantity of coal, from mine to thermal power station.

The above examples need installation of special bulk material handling system at source of raw materials, and also at process (consumption) unit. The raw materials being mined has to be temporarily stored in gigantic piles, to be retrieved on need and to be loaded in to railway – wagons / trucks. When such material arrived at cement /steel /power plant , some are to be unloaded ,stored, retrieved and finally to be consumed for making end product. Again, if the end product is a new bulk material, it will be further handling for storage, reclamation and onward transport.

The bulk material handling system consists of numerous equipments, which work in co-ordinated pre planned manner to achieve functional need. The slat conveyors are very preeminent and important equipment in such system, to ensure flow of material through various parts of the system.

2. The Slat Conveyor

Conveyor system is a mechanical system used in moving materials from one place to another and finds application in most processing and manufacturing industries such as: chemical, mechanical, automotive, mineral, pharmaceutical, electronics etc. There are various types of conveyor systems available such as gravity roller conveyor, belt conveyor, slat conveyor , bucket conveyor ,flexible conveyor ,belt driven live roller conveyor, chain conveyor , etc . The choice however depends on the volume to be transported, speed of transportation, size and weight of materials to be transported, height or distance of transportation, nature of material, method of production employed. Material handling equipment ranges from those that are operated manually to semi-automatic systems and to the ones with high degree of automation. The degree of automation however depends on handling requirements.

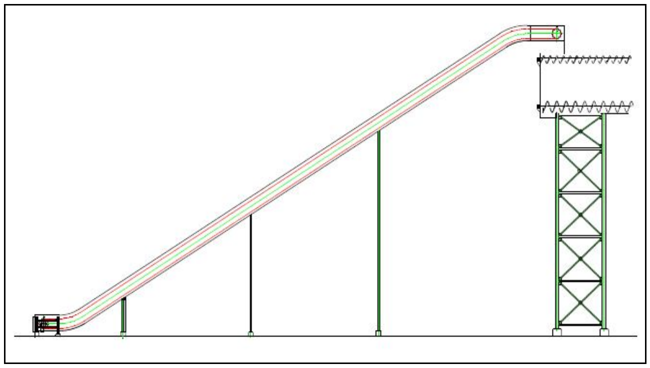
Material handling involves movement of material in a manufacturing section. It includes loading, moving and unloading of materials from one stage of manufacturing process to another.

A slat conveyor has the open links of chain drag material along the bottom of hard faced MS (mild steel) or SS (stainless steel) trough. The trough is fixed and slats are movable. The slats are the mechanical components that fixed between two strands of chain which drags the material from feeding end to the discharge end. These slats are available in different widths and lengths as per the site requirements. A small gap is made purposely between slats and trough. The slat conveyors are designed for horizontal and inclined transport of sawdust, chips, bagasse and other bulk goods. Slat conveyors are the traditional and most common means for distributing bagasse to boilers.

2.1. Input parameters required for development of slat conveyor

While designing a slat conveyor only four input parameters will be given by customer which are as follows-

- Guaranteed capacity = 33mtph
- Conveyor Length = 43.4 m
- Conveyor lift = 19.5 m
- Material to be handled = Bagasse (Density= 150Kg/m^3)
- Conveyor inclination = 31^0



3. Design of Slat Conveyor

In slat conveyor number of components are used like slat, trough, chain, chain resting part, roller, pin ,Sprocket, drive shaft, tail shaft, gear box, motor, etc. We have to design some of these components while using these components in system.

3.1. Slat Design

The two main requirements in the design of the conveyor are the ability to convey all the bagasse from the final mill and sufficient strength in all parts to withstand any expected working stresses. To meet the first requirement we must fix

- speed of conveyor,
- the width of flights,
- the spacing of flights and

Having from previous experience we fixed the –

- speed of conveyor =0.4 m/sec
- width of flights =1.5 m
- spacing of flights = 0.8 m

Also we know that, Density of material =150 kg /m^3

<u>3.1.1. Fill Factor</u>

The angle of inclination of conveyor changes the bagasse carrying capacity of conveyor. The load cross sectional area of inclined load is reduced when viewed in vertical plane as the surcharge angle is reduced perpendicular to slat.

An approximation of reduced capacity can be determined by multiplying horizontal capacity by the cosine of the inclination angle. This is called fill factor.

As the angle of inclination is 31^0.

Therefore ,fill factor = cos (31)

= 0.86

We know that ,

Conveyor capacity = $\frac{1}{2}$ * fill factor *slat width * slat height *slat and chain speed *material density *3600

We know that,

Conveyor capacity =38 mtph

Fill factor = 0.86

Slat width =1.5 m

Slat and chain speed = 0.4 m/sec

Material density =0.15

$\therefore$ 38 = 0.5*0.86*1.5 * slat height *0.4*0.15*3600

$\therefore$ Slat Height =0.2727 mm

Say 0.275 mm

First of all ,we will calculate the the cross sectional area of bagasse on conveyor for two cases-

- When conveyor is horizontal.

- When conveyor is inclined.

When slat conveyor is horizontal maximum bagasse will be occupied between the two slats. But when conveyor will become inclined then in such case the bagasse will fall down above its surcharge level. So we will design the conveyor for the case when slat conveyor is inclined.

At angle of slat is 90° :

i) When conveyor is horizontal.

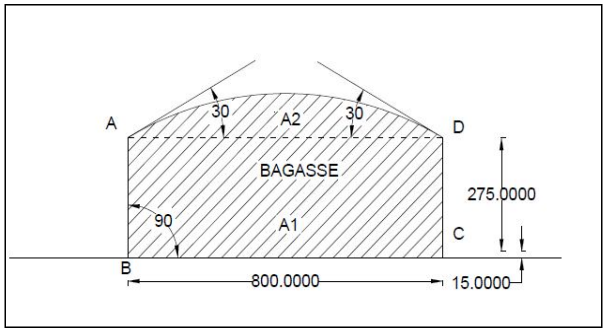


Figure 1: Cross-section of bagasse on horizontal conveyor

Material cross section on slat conveyor :

The material cross section on conveyor is formed by the trough profile on bottom side, and by surcharge angle for curved top. The experience shows that the material being carried on slat conveyor will have cross section as shown in figure.

The area is made up of two parts viz.A1 and A2 .The area A1 is known as water level fill area. The area A2 above water fill is known as top area. The water fill area A1 shape and magnitude is fixed by trough profile/shape. Regarding shape of top area A2, ISO considers it to be arc of parabola where as USA practice considers it to be an arc ends are inclined at surcharge angle α. It is obvious that the water fill area A1 is same for both the shape of arc. This topic explains the derivation of total cross section area A1+A2 with parabolic arc and also with circular arc. The derivation also includes the calculation of material height on conveyor.

Since we know that, height of slat is 275 mm i.e.0.275 m and their spacing between slat and trough is 15 mm i.e.0.015 m.

So the total height of slat will become 290 mm i.e.0.290 m.

i) When conveyor is inclined at 31^0:-

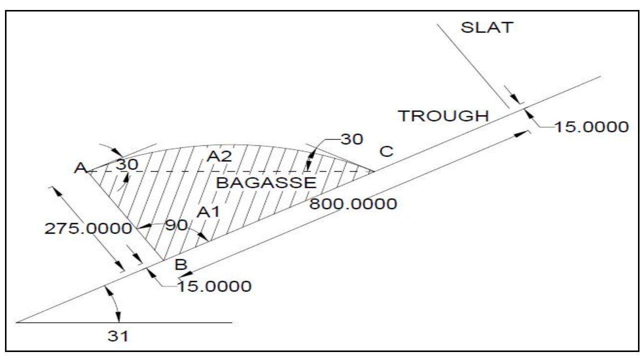


Figure 2: Cross-section of bagasse on inclined conveyor

Let

α = surcharge angle

=30° (For bagasse ,surcharge angle =30^0)

In ΔABC ,

Sin31= $\frac{AB}{AC}$

Therefore, AC = 0.563065 m

And, tan31= $\frac{AB}{BC}$

Therefore, BC = 0.482641 m

Now, Water fill area,

i.e. A(ΔABC) = A1

= $\frac{1}{2}$ * BC * AB

A(ΔABC) = 0.0700 m^2

Top area of parabola,

$A_2 = \frac{1}{6} * L^2 * \tan\alpha$
Here, L= Base= AC=0.563065 m
A_2 = 0.0305 m^2
Therefore, Total area = A_1+A_2
=0.100488 m^2
The total cross sectional area of bagasse is 0.100488 m^2 when slat angle is 90^0.
Design calculations:
Gauranted capacity : 33mtph
Design capacity : 38mtph
Conveyor length : 43.4 m
Conveyor lift : 19.5 m
Material handled : Bagasse (Density= 150Kg/m^3)
Lump size=-100 mm
Flight size = 275*1500mm wide
Flight spacing = 800 mm
Flight Thickness = 6 mm
Flight material= M.S. (Mild Steel, Density =7850Kg/m^3)
∵ We know that ,Flight mass = Flight volume *flight material density
∴ Flight mass = (0.275*1.5*0.006) *7850
∴ =19.428750 Kg.
As the spacing between two slats is 0.8 m.
∴ Flight mass per meter = $\frac{(0.275*1.5*0.006*7850)}{0.8}$
∴ Flight mass per meter =24.28594 Kg.
Material carrying run = Material is conveyed in forward motion.
Type of casing= Independent enclosed casing for forward run and return run.
Lift for forward run =19.5 m
Conveying capacity for forward run =33 mtph (Gauranted)
38 mtph (Design)
Material conveyed upper run = Fresh (wet) bagasse ; 150Kg/m^3 ;50% moisture.
Chain arrangement= double strand ; Each strand of 30 Kg/m ; two strands ;total 60 Kg/m,200 mm pitch ;
80 tonn Breaking load.
Chain mass per meter =30*2= 60Kg
Chain and flight travel speed =0.4 m/sec (24 m/min)
Chain pin diameter = 28 mm
Chain Roller diameter =75 mm
Type of motion for Chain and Flight =Rolling trough chain and rollers.
Type of motion for Bagasse =Dragging by Flights in bottom portion of casing.
Capacity calculation:
The total cross sectional area of bagasse is 0.100488 m^2.
∴ Volume of bagasse per slat /flight = (0.100488 *1.5) m^3.
∴ Mass of bagasse per slat /flight = (0.100488 *1.5*150) Kg.
=22.6098 Kg.
But spacing between two slats is 0.8 m.
∴ Mass of bagasse per meter =$\frac{(0.100488*1.5*150)}{0.8}$ Kg/m.
=28.26225 Kg/m.
Material height in upper run:
∵ We know that, Mass of bagasse per meter =28.26225 Kg/m.
We are considering that this mass of bagasse is spreaded uniformly over unit length.

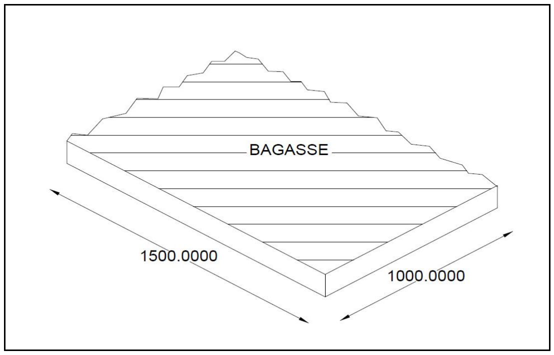


Figure 3: Height of bagasse layer

Therefore, Mass of bagasse =Length of layer *Width of layer *Height of layer* Density.

$\therefore$ 28.26225 = 1*1.5* Height of layer* 150

$\therefore$ Material Height of layer = $\frac{28.26225}{1*1.5*150}$ m

$\therefore$ = $\frac{28.26225}{1*1.5*150*0.0254}$ inch

= 4.945276 inch

Moving masses per meter of run :

Chain and flight mass per meter of run i.e. Rolling mass per meter of run =M_{cf}

$\therefore$ M_{cf} = Flight mass + Chain Mass

$\therefore$ M_{cf} = 24.28594 + 60

$\therefore$ M_{cf} = 84.28594 Kg/m

Mass of bagasse per meter =M_{mu} = 28.26225 Kg/m.

Conveying Resistance Factors:

Conveying Resistance Factors for rolling mass ,f_1

Friction coefficient steel pin on steel roller ,μ = 0.4

$\therefore f_{1\ =\ 0.4*}\frac{28}{75}$

= 0.1493 (for rolling mass)

Bagasse sliding / dragging factor , f_2 =0.35 to 0.45

Applicable to vertical load , f_2 = 0.45

Bagasse Horizontal pressure factor , f_3 = 0.0055

(For resistance = f_{3*}(Material Height in inch)^2

Upper run resistance per meter

Chain and Flight rolling i.e. Rolling Resistance = 1* M_{cf} * f_1

= 1* 84.28594 *0.1493 =12.64289 Kgf/m

Bagasse sliding /Dragging on Bottom casing = 1 * M_{mu} * f_2

=1 * 28.26225 * 0.45 = 12.71801 Kgf/m

Bagasse Rubbing on sides = 1 * f_3 * (Material Height in inch)^2

=1 * 0.0055 * $(4.945276)^2$ = 0.134507 Kgf/m

$\therefore$ Total upper resistance = Chain and Flight rolling i.e. Rolling Resistance + Bagasse sliding /Dragging on Bottom casing + Bagasse Rubbing on sides

=12.64289 +12.71801 +0.134507 =25.49541

Upper run resistance = (Conveyor length * Chain and Flight rolling i.e. Rolling Resistance) - (Conveyor Height * Chain and flight mass per meter of run i.e. Rolling mass per meter of run ,M_{cf})

= (43.4*12.64289) – (19.5 *84.28594) = - 1094.87 Kgf

Lower run resistance = (Conveyor length * Chain and Flight rolling i.e. Rolling Resistance) +(Conveyor length * Bagasse sliding /Dragging on Bottom casing) +(Conveyor length * Bagasse Rubbing on sides) +[Conveyor height *(Chain and flight mass per meter of run i.e. Rolling mass per meter of Run ,M_{cf} + Mass of bagasse per meter ,M_{mu})]

$\therefore$ Lower run resistance = 3301.19 Kgf

Total resistance ,R = Upper run resistance + Lower run resistance+[(Upper run resistance +Lower run resistance)* 15%]

= 2537.264 Kgf

Now,Power required at sprocket shaft = Total resistance ,R *$\frac{\text{Chain and flight travel speed}}{102}$

= 9.951148 KW
Since, Here,Drive efficiency =90 % i.e 0.9
∴ Power required at Motor shaft = Power required at sprocket shaft / Drive efficiency = 11.05683 KW
Since, Here, we are selected ,
Safety factor = 1.6
∴ Motor required in H.P.= (Power required at Motor shaft * Safety factor) / 0.75
=23.58787 H.P.
So ,we are using 25 H.P. motor.
Summary of design for slat conveyor:
Gauranted capacity : 33mtph
Design capacity : 38mtph
Conveyor length : 43.4 m
Conveyor lift : 19.5 m
Material handled : Bagasse (Density= 150Kg/m^3)
Lump size=-100 mm
Flight size = 275*1500mm wide
Flight spacing = 800 mm
Flight Thickness = 6 mm
Flight material= M.S. (Mild Steel, Density =7850Kg/m^3)
No.of teeth in driving chain sprocket = 10
No.of teeth in driven chain sprocket = 10
Torque transmitted by shaft= 18650969.91 N.mm
Diameter of shaft =100 mm
Overall efficiency of slat conveyor = 90 %
Power required to drive = 25 H.P.
Motor speed =1440 rpm

4. Conclusion

We wish to state that in our opinion the above method of conveying and storing the bagasse is by no means the ideal one ; the storage shed and the slat conveyor used overseas is considered far superior. Belt conveyors and slat conveyors as used in some mills appear to be an effortless means of conveying bagasse but there are limitations to these as regards a satisfactory method of feeding to the individual fire openings; also their limit of elevation appears to be between 30^0 and 35^0 .These limitations can, no doubt, be quite easily overcome.

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