Government College of Engineering and Research, Avasari(Khurd)

Department: Mechanical Engineering

Learning Resource Material (LRM)

Name of the course: Mechanical System Design **Course Code:** 402048

Name of the faculty: J. M. Arackal **Class:** BE(Mech)

SYLLABUS(Unit 3)

Unit 3: Design of Belt conveyer system for material handling (8 Hours)

System concept, basic principles, objectives of material handling system, unit load and containerization.
Belt conveyors, Flat belt and troughed belt conveyors, capacity of conveyor, rubber covered and fabric
ply belts, belt tensions, conveyor pulleys, belt idlers, tension take-up systems, power requirement of horizontal belt conveyors for frictional resistance of idler and pulleys.

Lecture Plan format:

Name of the course: Mechanical System Design **Course Code** 402048

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Unit No	Lecture No.	Topics to be covered	Text/Reference Book/ Web Reference
		UNIT 3	
3	1	System concept, basic principles, objectives of material handling system	1,2
3	2	Unit load and containerization. Belt conveyors, Flat belt and troughed belt conveyors	1,2
3	3	Capacity of conveyor, rubber covered and fabric ply belts	1,2
3	4	Belt tensions, conveyor pulleys, belt idlers, tension take-up systems	1,2
3	5	Power requirement of horizontal belt conveyors for frictional resistance of idler and pulleys.	1,2
3	6	Problems On Material Flow Capacity etc.	1,2
3	7	Problems On Material Flow Capacity etc.	1,2
3	8	Slack side to Tight side force calculation and Power Requirements	1,2

List of Text Books /Reference Books/ Web Reference

1-Bhandari V.B. ―Design of Machine Elements‖, Tata McGraw Hill Pub. Co. Ltd.

2-R.K. Jain- Machine Design, Khanna Publishers

3-Johnson R.C., ―Mechanical Design Synthesis with Optimization Applications‖, Von Nostrand Reynold Pub

Design of Material Handling System.

Material Handling

- Picking up Load
- Transporting
- Placing the load.

Types of Load

- Bulk load – Lumps of material, coal, sand stone.
- Unit Load – Rigid & Single. – machine boxes, container

Containerization

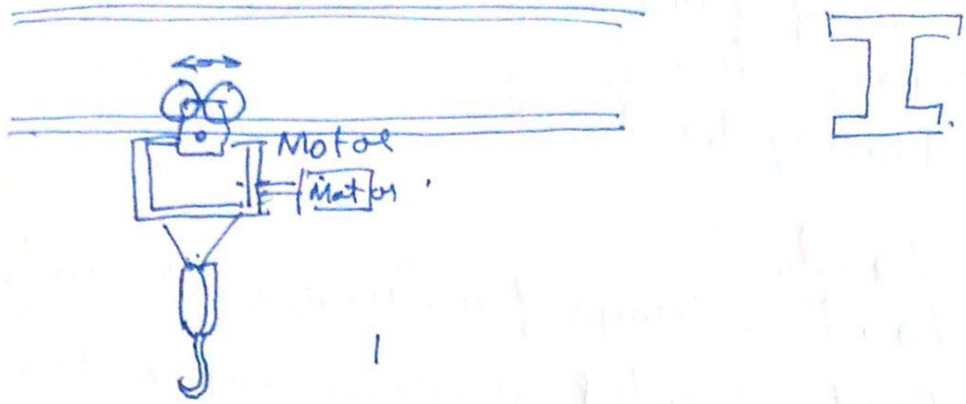
Special type of Unit Load.
converting bulk load to unit load.
size container based on load to be handled.
space available.

Classification of Material handling equipment

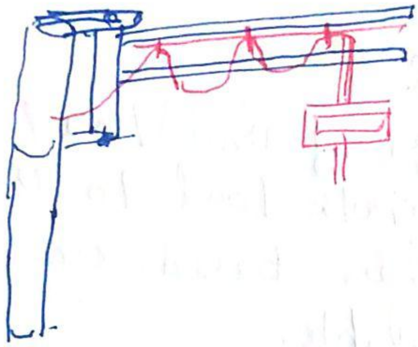
Material handling equipment

- Surface & Overhead equipment
- Conveying equipment
  - flat belt
  - troughened belt
- Hoisting equipment (vertical mo…)
  - Elevators.
    - Cage Elevators.
    - Vertical skip elevators
  - Cranes.
    - Jib cranes
    - Gantry Crane
  - Hoisting Machines
    - Jacks, pulley
    - Power house

Hoisting - power operated



Jib Crane.



Conveying equipments - Horizontal / Inclind directions

conveyors
- carry loads in horizontal & Inclined direction.
- Transfer rate of materials is high.
- can be placed on floor, or at higher level.
- Can carry material in extreme operating conditions - furnace, paint units, high pressure cleaning units

Types of Materials Handled by conveyors:

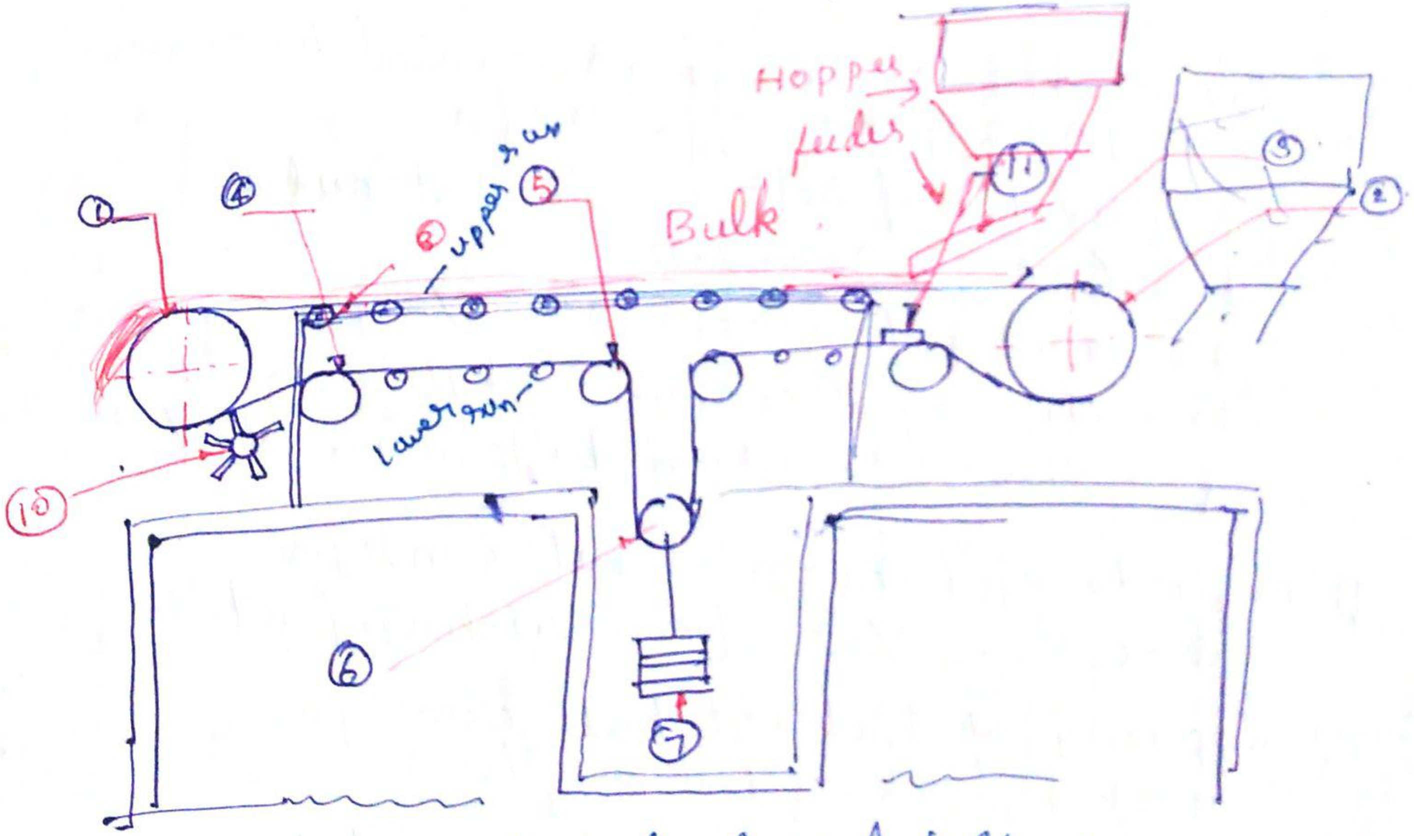
- Bulk materials
- Hazardous materials
- Loose materials
- Packages

Types of Conveyors

- Flat belt
- Troughed Belt conveyors
- Blanket Belt conveyors.
- woven wire Conveyors.
- chain conveyors.
- Apron conveyors
- screw conveyors

Flat belt conveyor.

1- Head Pulley.
2- Tail pulley
3- Conveyor belt
4- Snub pulley.
5- Bend pulleys
6 - Takeup pulley.
7 - Counterweight
8 - Idlers/Rollers
9 - Return Idlers.
10- Belt cleaner (Scraper).
11- Internal belt cleaner.



Layout of flat belt conveyor

Methods of feeding or loading to Flat belt conveyors

1) By hooper.
2) By preceeding Conveyor —

3) By process equipment
4) By travelling machine. (travelling hooper)

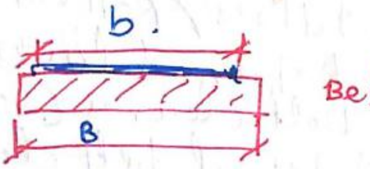
Troughed belt Conveyors.

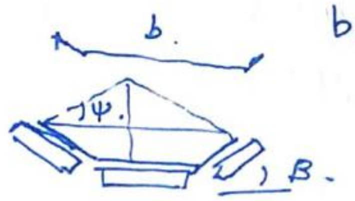
width of flat belt limits the volume carrying Capacity

Trough shape given by idler pulley.
nylon / Polymer / polyster belts are used.

Capacity of Belt Conveyors (Q).

B = width of the belt.
b = width of material stored on belt or effective belt width





Three Idler Troughed Belt

Rate at which material is carried by conveyor is known as capacity of conveyor.

B = width of belt. , v = belt speed m/s

$b = (0.9B - 0.05)$ m.

Q = Capacity of conveyor in m^3/s.

M = Capacity of conveyor in kg/s.

ρ = mass density of bulk material kg/m³

1) Capacity of horizontal belt conveyor

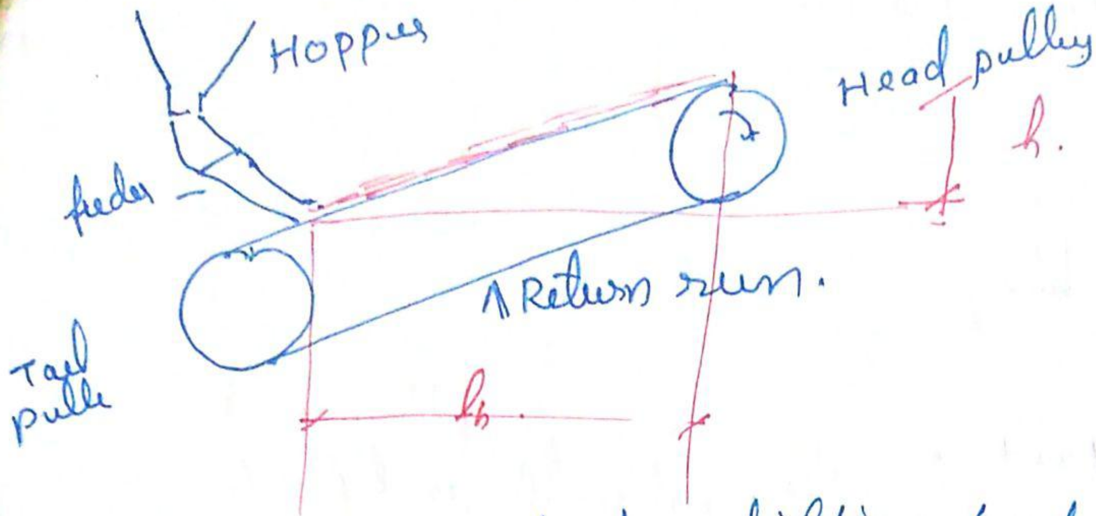
$Q = C b^2 v$ (m^3/s). [C = Surcharge factor]

2) Capacity of Inclined belt conveyor

$Q = k b^2 v$ k = flowability factor

⇒ standard Belt widths are there,

Power Requirement of Belt pulley Conveyor



– Power required for lifting Load.

$$\text{Power} = \frac{WD}{S}$$

$$= \frac{\text{mass lifted} \times g \times h}{\text{time}(s)}$$

$$= \frac{M \times g h}{\text{Secon}} \quad [M = kg/s]$$

we have $\rho \times Q = M$.

$$\left(\frac{kg}{m^3} \times \frac{m^3}{s}\right)$$

$$\text{Power } (P_e) = \frac{\rho Q g h}{1000} \text{ kw}$$

– Power required for overcoming frictional resistance.

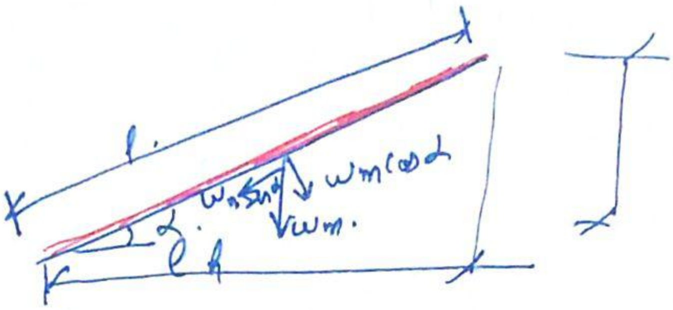
$$P_f = \frac{C_0 \rho Q g L}{1000} \text{ kw} \quad [L = \text{length of the belt}]$$

$$P = P_e + P_f.$$

C_0 = specific friction factor

Analysis of power requirement of Belt conveyors

1) Load resistance due to lifting of Material



l = length of load carrying run of belt.
h = height through which material is lifted.
l_r = length of return run of belt.
v = belt speed (m/s).
m_m = material carried by conveyor per unit length of belt (kg/m).
α = angle of inclination of belt.
Total load carrying run of the belt is

$W_m = m_m \times l \times g$.

This is resolved as.

$W_m \cos\alpha = m_m l g \cos\alpha$ (acts as normal reaction for idlers)

$W_m \sin\alpha = m_m l g \sin\alpha$ (direction opposite to belt motion & its termed as load resistance)

$= m_m l g \sin\alpha$

$F_m = m_m g h$ (component along the belt)

A horizontal flat belt conveyor is used for transporting the bulk material having mass density of 2000 kg/m³. The surcharge factor 'c' for the flat belt is 0.075, while the belt width is 800 mm. If the belt speed is 1.75 m/s determine the capacity of conveyor. (Q & M).

A) we have $Q = cb^2 v$. (m^3/s)

where $b = (0.9B - 0.05)$ m.

$c = 0.075$.

$\therefore Q = 0.075(0.9 \times .8 - 0.05)^2 \times 1.75$

$Q = 212.1\ m^3/hr$.

$m = \rho Q$ kg/h.

$= 2000 \times 212.1$

$= 424.2 \times 10^3$ kg/hr $= 424.2$ ton/hr.

Q) A three Idler, troughed belt horizontal conveyor is tobe used for transporting 350 ton/hr of mineral ore having weight density of 16700 N/m³. The surcharge factor 'c' for the three idler troughed belt is 0.1. If the belt speed is 120 m/min. Select the standard belt width for the conveyor belt.

Available standard belt widths are,

400, 450, 500, 600, 650, 750, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000 mm

$Q = c b^2 v.$

$b = (0.9B - 0.05)$

$v = \frac{120}{60} = 2 m/s.$

$\frac{kg}{m}$

$m = \rho Q$

$M = \frac{kg}{m^3} \times \frac{m^3}{s}$

we have. $M = \rho Q$.

$M = \frac{350 \times 10^3}{3600} = 97.2 kg/s.$

$\therefore 97.2 = \rho Q$

$\rho = 16700 N/m^3 = \frac{16700}{9.81} = 1702.34 kg/m^3$

$\therefore Q = \frac{97.2}{\rho} = \frac{97.2}{1702.34}$

$\Rightarrow Q = C b^2 v.$

$b = \sqrt{\frac{Q}{Cv}} = \sqrt{\frac{97.2}{1702.34 \times 0.1 \times 2}}$

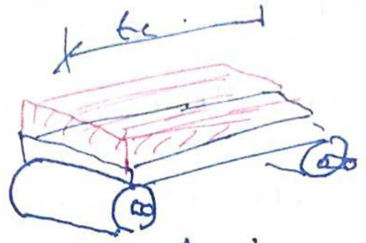
$b = 0.534.$

$\Rightarrow (0.9B - 0.05) = 0.534 m$

$\therefore \boxed{B = 650 mm}$

Analysis of

2) Frictional resistance. Due to Idlers



m_m = mass/unit ~~length~~ of mass of material carried by conveyor / unit belt length

m_b = mass of belt / ~~un~~ length.

m_i = mass of each idler.

t_c = pitch of carrying run idlers

t_r = pitch of return run idlers

Z_c = no of carrying run idlers

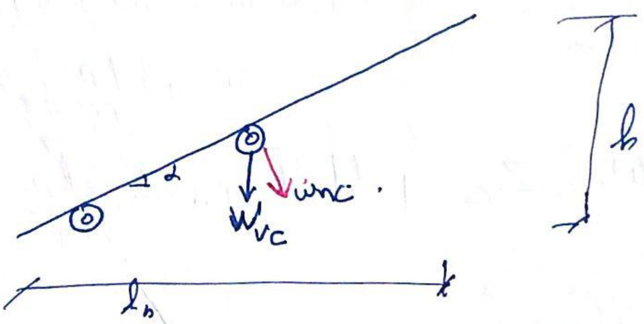
Z_r = no of return run idlers

d_r = dia of idler

d_p = dia of idler pin.

μ_r = coefficient of friction between idler & belt.

μ_p = coefficient of friction between idler & idler pin



vertical load on each idler is

$w_{vc} = (m_b + m_m).g\, t_c.$

$w_{nc} = (m_b + m_m) g\, t_c \cos\alpha.$

∴ frictional force.

$$\mu_r W_{rc} = \mu_r (m_m + m_b)\, g\, t_c \cos\alpha.$$

Total frictional force

$$\mu_r W_{rc} Z_c = \mu_r (m_b + m_m)(g\, t_c \cos\alpha)(Z_c).$$

$$= \mu_r (m_m + m_b)\, g\, l \cos\alpha \quad [\because t_c Z_c = l]$$

$$\boxed{\mu_r W_{rc} Z_c = \mu_r (m_m + m_b)\, g\, l}$$

Load on the pin of idler (each pin)

$$W_{pin} = W_{rc} + m_i g.$$

$$= (m_m + m_b)\, g\, t_c + m_i g.$$

frictional resistance per pin.

$$\mu W_{pin} = \mu[(m_m + m_b) g\, t_c + m_i g].$$

∴ Total frictional resistance

$$\boxed{\mu_p W_{pin} \times Z_c = \mu[(m_m + m_b)\, g\, t_c + m_i g] Z_c.}$$

∴ Total frictional resistance.

~~= μt~~

equivalent friction due to pin & roller.

is

$$\mu_p W_{pin} \times Z_c \frac{d_p}{d_r} = \mu\left[(m_m + m_b)\, g\, t_c \frac{d_p}{d_r} + m_i g \frac{d_p}{d_r}\right] Z_c.$$

∴ Total frictional resistance due to carrying run idlers.

$$= \mu_r W_{rc} Z_c + \mu_p W_{pin} Z_c \frac{d_p}{d_r}.$$

$$\boxed{F_{CRI} = f_c \left(m_m + m_b + \frac{m_i Z_c}{l}\right) g\, l.}$$

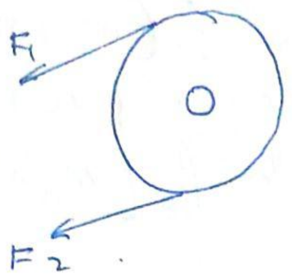
f_c = friction factor

Frictional resistance due to return idlers.

$$F_{r_r} = f_c\left[m_b + \frac{m_i z_r}{l}\right] g\, l_s$$

Frictional Resistance due at Pulley.

Let



& m_p = mass of pulley

d_B = dia of bearing

D_B = Dia of pulley.

$$F_P = \mu\left[(F_1 + F_2) + m_p g\right] \frac{d_B}{D_B}$$

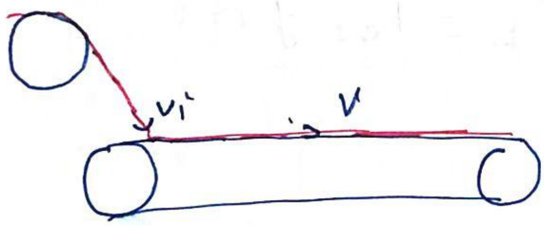
(equivalent)

∴ Emperical relation

$$F_P = \epsilon F_1$$

where ϵ = angle of lap (or snub) factor for pulley.

4) Resistance at Loading station.



$$F_L = M(v - v_1)$$

∴ M = mass of material (kg/s)

5) Frictional resistance at Unloading station

$$F_U = (3.1 \text{ to } 3.6)\, m_m\, g\, B$$

6) Frictional resistance at Cleaning station.

$$F_{CL} = K_{CL}\, g\, B.$$

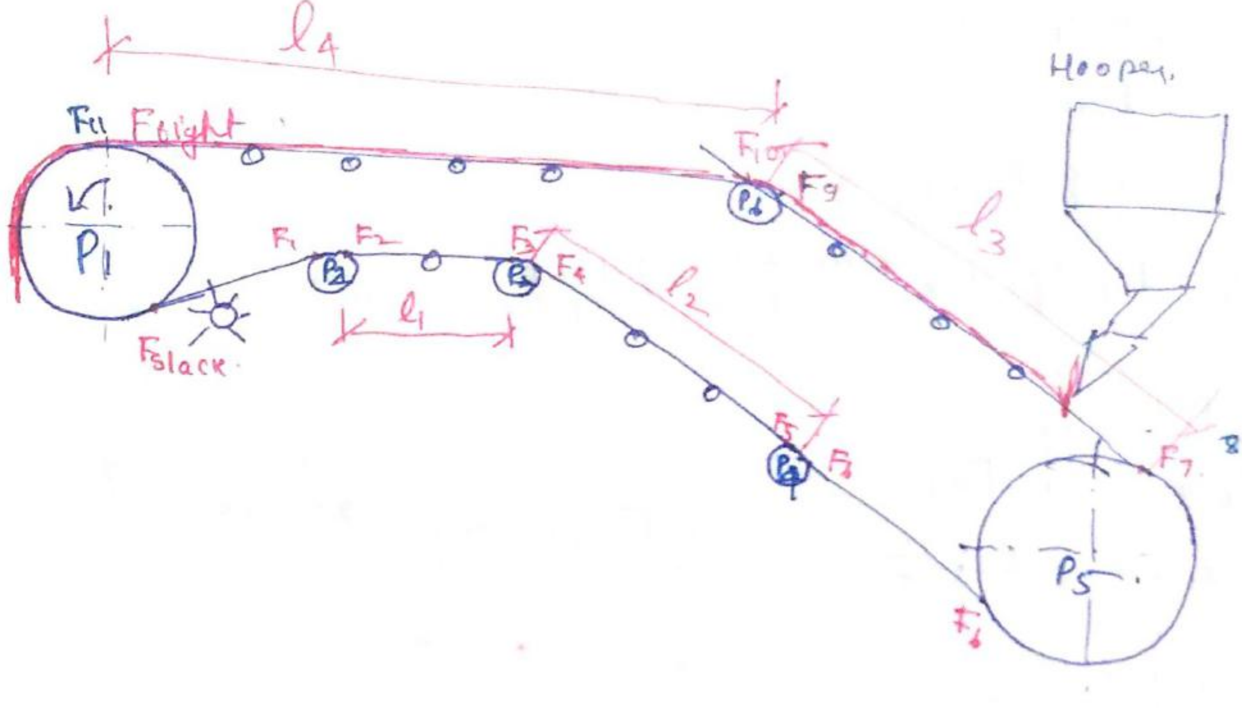
	Resisting force.	Expression.
1.	Load due to lifting of material	$F_m = m_m g h$.
2	Frictional resistance due to Idlers.	$F_{cr} = f_c \left(m_m + m_b + \frac{m_i z_c}{l} \right) g l$ (cr – carry run) $F_{rr} = f_c \left(m_b + \frac{m_i z_r}{l} \right) g l_r$.
3	Frictional resistance due to pulley	$F_p = \mu_p W \frac{d_b}{D_p}$ or $F_p = \epsilon F_{p_1}$.
4	Resistance at Loading station	$F_L = M(V - V_i)$.
5	Frictional Resistance at Unloading (F_u) (Removal by plough)	$F_u = (3.1 \text{ to } 3.6)\, m_m g B$.
6	Frictional Resistance at cleaning station (F_{cL})	$F_{cL} = K_{cL}\, g B$.

antiun idlers.

5

6

Belt tensions @ Various points



The belt tension at every succeeding point is equal to the belt tension at the preceding point plus the resulting force within the section between the two points.

Let F_{slack} = Effective tension in slack side.

F_{tight} = Effective tension in tight side.

At initial point. [start where belt leaves & end when it comes back to drive]

$$F_i = F_{slack}$$

At point 1 $F_1 = F_{slack} + F_{cL}$

$$= F_{slack} + K_{cL}\, g\, B.$$

At point 2 $F_2 = F_1 + F_{p2}$.

$$= F_1 + \epsilon_{p2} F_1.$$

At point 3 $F_3 = F_2 + F_{rr}$

$$F_3 = F_2 + f_c \left[m_b + \frac{m_i z_r}{l_1} \right] g\, l_1$$

At point 4

$F_4 = F_3 + F_{P3}$

$= F_3 + \epsilon_{P3} F_3$.

At point 5

$F_5 = F_4 + F_{r4}$.

$F_5 = F_4 + f_c \left(m_b + \frac{m_i z_{r2}}{l_2} \right) g\, l_2$.

At point 6.

$F_6 = F_5 + F_{P5}$

$= F_5 + \epsilon_{P4} F_5$.   [ϵ_P = snub for respective pulley]

At point 7.

$F_7 = F_6 + F_{P6}$

$= F_6 + \epsilon_{P5} F_6$.

At point 8

$F_8 = F_7 + F_L$.

$F_8 = F_7 + M (v - v_i)$.

At point 9

$F_9 = F_8 + F_{Cr3} + F_m$

$F_9 = F_8 + f_c \left[m_m + m_b + \frac{m_i Z_{c3}}{l_3} \right] g l_3 + m_m g h$.

At point 10

$F_{10} = F_9 + \epsilon_{P6} F_9$.

At point 11.

$F_{11} = F_{10} + F_{Cr4} + F_v$.

At final point

$F_{tight} = F_{11} + F_{P1}$.

$= F_{11} + \epsilon_{P1} F_{11}$.

Again we have

$$\frac{F_{tight}}{F_{slack}} = e^{\mu \theta}$$

P_o = Power required to drive pulley $= \frac{(F_{tight} - F_{slack})V}{1000}$ kW

P(input power) $= \frac{P_o}{\eta}$

Selection of number of plies for conveyor belts

Let F_{bs} = breaking strength of conveyor belt

$F_{bs} = (FOS)\, F_{tmax}$ [F_{tmax} = Max tension in the belt].

$F_{bs} = S_{ut}\, B\, Z_p$

where S_u = UTS per unit width of ply.

Z_p = No of plies

Min. Dia of Pulley

$D_{min} = k_1 k_2 Z_p$

when k_1 = Materia factor for plies

k_2 = Belt tension & arc of contact factor

Q) A belt conveyor is to be designed to carry the Bulk material at the rate of 300×10^3 kg/hr with following details.

Bulk density of the material = 800 kg/m³.

Angle of repose of the bulk material = 15°

Belt speed = 10 km/hr.

Material factor for plies, k_1 = 2

Belt tension & arc of contact factor, k_2 = 63

At point 4

No of plies for the belt = 4.
Surcharge factor 15° = 0.075.
Determine:
i) Suitable width for the belt
ii) Dia & length of Drive pulley.

Ans). $Q = cb^2v$.

$b = (0.9B - 0.05)$.

$M = \rho Q$.

$\therefore \rho = \frac{M}{}$ $\quad M = Cb^2v\rho$.

$M = C(0.9B - 0.05)^2 \rho v$ — ①

$800 = 0.075(0.9B - 0.05)$

$M = \frac{300 \times 10^3}{3600}$ kg/s = 83.33 kg/s.

$v = 10$ km/hr $= \frac{10 \times 10^3}{3600} = 2.77$ m/s.

M = . put all in ①.

$83.33 = 0.075(0.9B - 0.05)^2 \times 2.77 \times 800$

$(0.9B - 0.05)^2 = ~~401.123~~\ 0.5$.

$0.9B - 0.05 = 0.708$

$B = 842.3$ mm

$\boxed{B \cong 850 \text{ mm}}$

ii) Dia of pulley $= k_1 k_2 z_p$

$= ~~2~~ \times 63 \times 4 = 504$.

≈ 510 mm

length of pulley $= B + 150$

$= ~~510+150~~$

$= 850 + 150$

$= 1000$ mm

we have.

$$V = \frac{\pi D N}{60}.$$

$$\frac{90}{60} = \frac{\pi \times \cdot 480 \times N}{60}$$

N = 60 rpm.

$\therefore$ Reduction ratio = $\frac{1440}{60}$

G = 24.

Q) A triple ply belt conveyor is required to. transport 1.5 ton of iron ore per hour. through a distance of ~~800~~ 1000 m. on ground & height of 300 m. The permissible belt speed is ~~75~~ 90 m/min. If the mass density of iron ore is 2.5 ton/cubic metre. determine.

i) belt width.

ii) The dia of the drive pulley.

iii) The reduction ratio of gear reducer. If. electric motor. speed is 1440 rpm.

use following data:

Belt Inclination (α).	$10^\circ - 15^\circ$	16-20	21-25	26-30	31-35
flowability. factor K.	2.65×10^{-4}.	2.5×10^{-4}.	2.35×10^{-4}	2.20×10^{-4}	2.05×10^{-4}.

Standard belt width: 400, 450, 500, 600, 650, 750, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000 mm.

Material factor for plies for carbon belt: $K_1 = 2$

Belt tension & arc of contact factor: $K_2 = 80$.

$M = 2 \text{ tons/hr} = 2 \times 10^3 \text{ kg/hr}$

$V = 90 \text{ m/min}$

$\rho = 2.5 \times 10^3 / m^3$

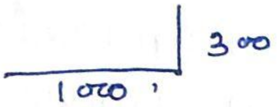
we have.

$Q = k b v^2 = k b v^2$ (Inclined belt)

& $M = \rho Q$.

$M = \rho k b v^2$

for selecting k we need to find inclination α.



$\tan\alpha = \frac{300}{1000}$ ∴

$\boxed{\alpha = 16.7^\circ}$

∴ from table

$k = 2.5 \times 10^{-4}$.

$b = (0.9B - 0.05)$.

∴ $M = \rho k b v^2$.

$M = \frac{2 \times 10^3}{3600} = 0.55 \text{ kg/s}$.

$k = 2.5 \times 10^{-4}$.

$\rho = 2.5 \times 10^3 \text{ kg/m}^3$.

$v = \frac{90}{60} = 1.5 \text{ m/min}$

$0.55 = 2.5 \times 10^3 \times 2.5 \times 10^{-4} \times 1.5 (0.9B - 0.05)^2$.

∴ $0.9B - 0.05 =$

$\boxed{B \cong 1000 \text{ mm}}$ - Ans

ii) Dia of pulley $= k_1 k_2 Z p$.

$= 2 \times 80 \times 3$

$D = 480 \text{ mm}$

7) of MS Question Bank.

Ans). $M = 4$ Tons/hr.

$V = 3$ m/s.

$\rho = 2.5$ tons/m^3.

$K_1 = 2.0$

$K_2 = 80$

i) The max suitable belt inclination.
16-20°.
$\therefore K = 2.5 \times 10^{-4}$.

ii) $D_p = K_1 K_2 Z_p$.

$= 2 \times 80 \times 3$.

$= 480$ mm

iii). we have $V = 3$ m/s

$V = \frac{\pi D N}{60}$ $\therefore 3 = \frac{\pi \times 0.480 \times N}{60}$.

$\therefore$ **N = 119 rpm**

$\therefore$ Gear box reduction $= \frac{1440}{119} = 12.06$

Q) The following data refers to a flat belt conveyor for transporting crushed rock.

Mass density ρ $= 2$ Ton/m^3.

Belt speed V $= 1.75$ m/s

Belt width B. $= 0.8$ m.

Surcharge angle α $= 25°$

Determine the capacity of the belt conveyor in Tons/hr.

$Q = c\, b^2 v$ [c = surcharge factor]

$= k b v^2$ [k = flowability factor]

for $\alpha = 25^\circ$ $\quad k = 2.35 \times 10^{-4}$.

$Q = k b^2 v$. — ①

$b = (0.9B - 0.05)$.

$kg/s = \frac{kg}{m^3} \times \frac{m^3}{s}$

$M = \rho Q$. — ②.

$m = \rho Q$.

: from above

$M = \rho k b^2 v$.

$b = (0.9B - 0.05)$

$= (0.9 \times 0.8 - 0.05)\,m.$

$$\boxed{b = 0.67\ m.}$$

$M = (2) \times (2.35 \times 10^{-4}) \times (1.75)^2$.

~~$M = 1.44 \times 10^{-3}$~~ Tons/sec.

$M = \rho k b^2 v$

$M = 2 \times (2.35 \times 10^{-4})(0.67)^2 \times 1.75^2 = 6.46 \times 10^{-4}$ Ton/sec.

$M = 2.32$ Ton/hr.

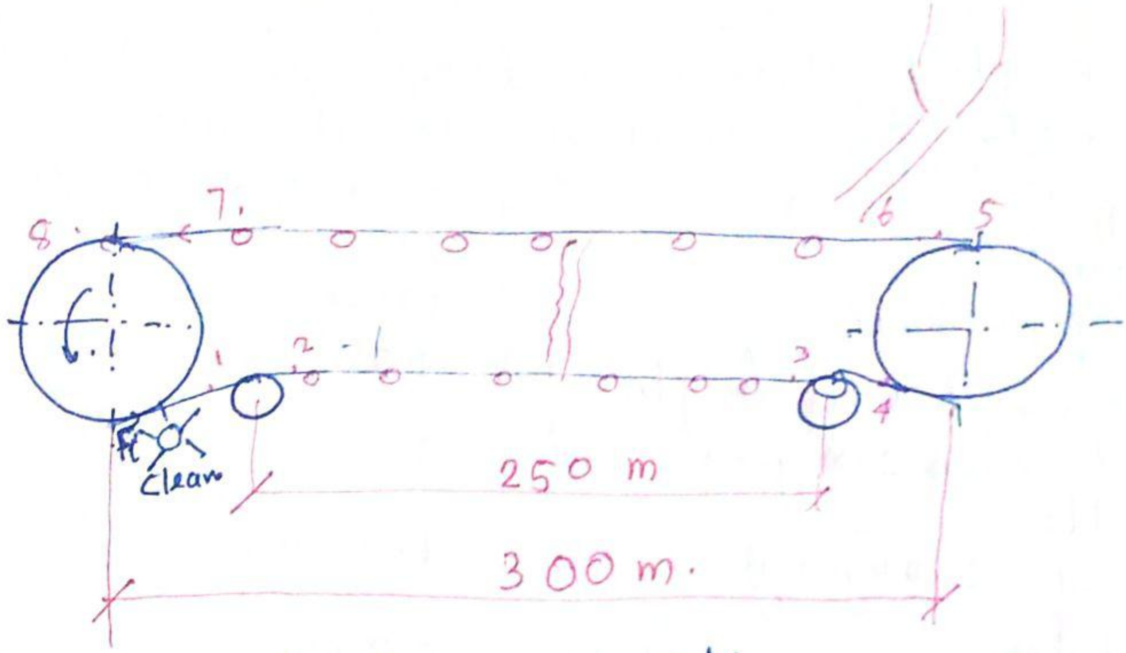
) The following data refers to a horizontal belt conveyor for carrying bulk material.

- Capacity of conveyor - 250 Metric Tons/hr
- Belt speed - 1.5 m/s.
- Width of the belt - 1200 mm.
- Belt mass per unit length - 18.6 kg/m.
- Mass of each carrying run idler - 25 kg.
- Pitch of carrying run idler - 1.0 m.
- Pitch of return run idler - 2.0 m.
- Friction factor for idler - 0.02
- Snub factor for snub pulley - 0.03.
- Snub factor for drive & tail pulley - 0.06.
- Drive & tail pulley dimensions (dia) - 500 mm.
- Frictional resistance due to belt cleaner, where - (100 B) N.
  B = belt width, m
- Angle of lap on drive pulley - 200°
- Coefficient of friction between belt & drive pulley - 0.4.
- Drive efficiency - 90%.
- Motor speed - 1440

Assuming that the bulk material is carried over a length of 300 meters & neglecting resistance at the loading station, determine:

(i) the reduction ratio of gear box &

(ii) the power required to drive the belt.



z_r = no of return run idlers.

$\&$ pitch $= t_r = \dfrac{l}{(z_r+1)}$.

$$2 = \frac{250}{z_r+1}$$

$$\Rightarrow \boxed{z_r = 124}$$

similarly pitch of carrying run idlers.

$t_c =$.

$$\& . \ t_c = \frac{l}{(z_c+1)}.$$

$$1 = \frac{300}{z_c+1} \qquad \boxed{z_c = 299}$$

$F_{initial} = F_{slack}$.

At point 1

$F_1 = F_{slack} + F_{cleaner}$

$= F_{slack} + 100B$.

$= F_{slac} + (100 \times 1.2)$.

$$\boxed{F_1 = (F_s + 120)}$$

At 2.

$F_2 = F_1 + F_{pulley}$

$= F_1 + \epsilon F_1$

$= (F_{slack} + 120) + 0.03(F_{slack} + 120)$.

$= 1.03\,[F_{slack} + 120]$.

$$F_2 = 1.03\,F_{slack} + 123.6$$

At point 3

$F_3 = F_2 + F_{RR}$.

$F_{RR} = f_c\left(m_b + \frac{m_i z_s}{l_i}\right) g\, l_i$.

Here $m_b = 18.6\ kg/m$.

$m_i = 25$.

$z_s = 124$.

$l_i = 250$.

$f_c = 0.02$.

$F_{RR} = 0.02\left(18.6 + \frac{25 \times 124}{250}\right) \times 9.81 \times 250$.

$F_{RR} = 1520.55$.

$\therefore F_3 = F_2 + F_{RR}$

$F_3 = 1.03\,F_{slack} + 123.6 + 1520.55$

$$F_3 = 1.03\,F_{slack} + 1644.15\ N$$

At point 4.

$F_4 = F_3 + \epsilon F_3$.

$= (1+\epsilon) F_3$.

$F_4 = (1 + 0.03) F_3$.

$= (1.03)\,[1.03\,F_{slack} + 1644.15\ N$.

$$F_4 = 1.061\,F_{slack} + 1693.5\ N$$

At 5.

$F_5 = F_4 + \epsilon F_4.$

$F_5 = (1 + \epsilon_D) F_4$

$F_5 = (1 + 0.06) F_4.$

$F_5 = (1.06)(1.061 F_{slack} + 1693.5)$

$$\boxed{F_5 = 1.125 F_{slack} + 1795 \text{ N}}$$

At point 6

$F_6 = F_5 + F_{load}$

$F_6 = 1.125 F_{slack} + 1795 + M(v - v_1)$

$v_1 = 1.5$, let $v - v_1 = 1.5 - 0.5 = 1 \text{ m/s}$

$F_6 = 1.125 F_{slack} + 1795 + M(1.)$.

$$M = \frac{250 \times 10^3}{3600} = 69.44 \text{ kg/s}.$$

~~$F_6 = 1.125 F_{slack} + 69.4$~~

$$\boxed{F_6 = 1.125 F_{slack} + 1864.4}$$

At 7

$F_7 = F_6 + F_{CR}$

$$F_{CR} = f_c \left(m_m + m_b + \frac{m_t Z_c}{e}\right) l.$$

we have $M = \frac{kg}{s}$.

$$m_m = \frac{kg}{m} = \left(\frac{kg}{s}\right) \times \left(\frac{s}{m}\right) = \frac{M}{v} = \frac{69.44}{1.5}.$$

$m_m = 46.3.$

$$F_{CR} = 0.02 \left[46.3 + 18.6 + \frac{30 \times 289}{300}\right] \times 300 \times 9.8$$

$F_{CR} = 5580.$

$F_7 = 1.125 F_{slack} + 1864.4 + 5580$

$$\boxed{F_7 = 1.125 F_{slack} + 7444.33}$$

all at point 8

$F_8 = F_7 + \epsilon_p F_7$.

~~$= 1.125 F_{slac} + 0.06$~~

$= F_7 + 0.06 F_7$.

$F_8 = (1.06) F_7$.

$F_8 = (1.06)(1.125 F_{slack} + 7444.33)$

$F_{tight} = F_8 = 1.192 F_{slack} + 7891$

Also $\mu = 0.4$.

$$\frac{F_{tight}}{F_{slack}} = e^{\mu\theta}.$$

$\theta = 200°$

$\pi^c = 180°$

$? = 200$

$$? = \frac{200 \times \pi}{180} = 3.49800$$

$$\frac{F_{tight}}{F_{slack}} = e^{3.49 \times 0.4} = 4.04.$$

$\therefore \quad 4.04 F_{slack} = 1.192 F_{slack} + 7891.$

$F_{slack} = 2771$ N

$F_{tight} = 11194$ N

$$\therefore \text{Power required} = \frac{(F_{tight} - F_{slack})\, v}{1000}$$

$$= \frac{(11194 - 2771) \times 1.5}{1000}$$

$= 12.63$ kW.

$\eta = 0.9$

$$\therefore \text{Input power} = \frac{12.63}{0.9} = 14 \text{ kW}$$