Design of Conveyor Belt

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ABSTRACT

A belt conveyor system is one of many types of conveyor systems. A belt conveyor system consists of two or more pulleys (sometimes referred to as drums), with an endless loop of carrying medium—the conveyor belt—that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley. There are two main industrial classes of belt conveyors; Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport large volumes of resources and agricultural materials, such as grain, salt, coal, ore, sand, overburden and more.

I. INTRODUCTION

Belt conveyors have attained a dominant position in transporting bulk materials due to such inherent advantages as their economy and safety of operation, reliability, versatility, and practically unlimited range of capacities. In addition, they are suitable for performing numerous processing functions in connection with their normal purpose of providing a continuous flow of material between operations. Recently, their conformity to environmental requirements has provided a further incentive for selection of belt conveyors over other means of transportation.

Low labour and low energy requirements are fundamental with belt conveyors as compared with other means of transportation. The dramatic increase in these operating costs since the oil crisis of the seventies has placed conveyors in an extremely favourable position for applications that were not considered previously. Belt conveyor manufacturers have consistently anticipated the needs of industry with improvements in designs and with components that have exceeded all known requirements. Reliability and safety are outstanding now that stronger and more durable belts are available, as well as greatly improved mechanical parts and highly sophisticated electrical controls and safety devices. Illustrated and described in this chapter are some of the advantages of belt conveyors, which are performing a wide variety of interplant functions better and/or in a more innovative manner than is possible with other means of transporting bulk materials. Also included are examples of relatively long-distance belt conveyor systems which are being used extensively because they combine such important benefits as reliability, safety, and low cost per ton of material transported.

II. THEORETICAL DETAILS

Conveyors are durable and reliable components used in automated distribution and warehousing. In combination with computer controlled pallet handling equipment this allows for more efficient retail, wholesale, and manufacturing distribution. It is considered a labour saving system that allows large volumes to move rapidly through a process, allowing companies to ship or receive higher volumes with smaller storage space and with less labour expense.

Rubber conveyor belts are commonly used to convey items with irregular bottom surfaces, small items that would fall in between rollers (e.g. a sushi conveyor bar), or bags of product that would sag between rollers. Belt conveyors are generally fairly similar in construction consisting of a metal frame with rollers at either end of a flat metal bed. The belt is looped around each of the rollers and when one of the rollers is powered (by an electrical motor) the belting slides across the solid metal frame bed, moving the product. In heavy use applications the beds which the belting is pulled over are replaced with rollers. The rollers allow weight to be conveyed as they reduce the amount of friction generated from the heavier loading on the belting.

Belt conveyors can now be manufactured with curved sections which use tapered rollers and curved belting to convey products around a corner. These conveyor systems are commonly used in postal sorting offices and airport baggage handling systems. A sandwich belt conveyor uses two conveyor belts, face-to-face, to firmly contain the item being carried, making steep incline and even vertical-lift runs achievable.

Belt conveyors are the most commonly used powered conveyors because they are the most versatile and the least expensive. Product is conveyed directly on the belt so both regular and irregular shaped objects, large or small, light and heavy, can be transported successfully. These conveyors should use only the highest quality premium belting products, which reduces belt stretch and results in less maintenance for tension adjustments. Belt conveyors can be used to transport product in a straight line or through changes in elevation or direction. In certain applications they can also be used for static accumulation or cartons.

Major benefits of automating with the conveyors are that, it reduces the repetitive tasks, as well as, the associated costs with it. Establishing or setting up a Belt Conveyors can reduce injuries, which are generally caused in repetitive tasks. In addition, your employees can be fully utilized for and can be of great help in other projects. The conveyor belt, also allow easy movement between several different processes.

It is right to say conveyors, allow the transport of large amounts of products without manual loading or workers not even touching the product. Belt conveyor solution is cost-effective, which allow for increased productivity immediately. Plus, with employees interacting with the product less often fewer injuries are likely to occur, saving cost and risk.

While taking a serious look at the conveyor, we find it one of the least expensive method of moving material or products from small distance to over long distances. Plus, it does not degrade the items, which are being transported in anyway. Conveying systems may have different heights allowing for a productive method of transporting goods from one location to another. While the accessories are being moved on the belt conveyor they can easily be observed.. An inclined conveyor belt can use belts that have cleats, reducing the possibility of products rolling backwards. In addition, sidewalls are at times added to the conveying system, so products stay on the conveyor ensuring smooth transport.

Belt conveyors are the systems that are designed to move any conceivable product. Conveyor belts, can transport goods horizontally, then inclined Belt Conveyor, and back. A big advantage of the belt conveyor versus other types of conveyors is that, it uses less horsepower to move goods. The product does not move while on the belt, meaning less power is needed to transport. In addition, some conveyor belt systems have a pivoted end allowing for a convenient method of stacking at the end of a production line.

To conclude, I summarize, conveyors are most common in almost all the industries, whether big or small. It is more cost-effective to move goods with conveyors than to have army of workers to do the task saving labour cost and risk of injuries. Conveying uses the hands-off approach to moving goods, and therefore increases production. It is easy to follow the flow of production, when conveying is implemented. Fitting a conveyor belt with sidewalls makes sure the product stays on the belt. In this era of cost efficiency, it just makes sense to automate with a conveyor belt. So it make sense use conveyors and make your material movement easy, cost effective, saving labour cost and risk of injuries and save products from degrading. Use this innovative idea to increase production.

3.2.2 Reliability, Safety and Availability

The reliability of belt conveyors has been proven over decades and in practically every industry. They are operating with the utmost reliability, many serving vital process units whose very success depends on continuous operation, such as handling coal in power plants, and transporting raw bulk materials in steel plants, cement plants, paper mills, and to and from ships in ports, where downtime is very costly.

Belt conveyors operate with an extremely high degree of safety. Few personnel are required for operation and they are exposed to fewer hazards than with other means of transportation. Material is contained on the belt and personnel are not endangered by falling lumps or the malfunction of huge, unwieldy transport vehicles. Such vehicles also involve public liability, whether they operate over highways or in other areas accessible to the public. Also, conveyors offer less hazards to careless personnel than is inherent in other means of transporting bulk materials. The conveyor equipment itself can be protected from overload and malfunction by built-in mechanical and electrical safety devices.

3.2.3 Environmental Advantages

Belt conveyors are environmentally more acceptable than other means of transporting bulk materials; they neither pollute the air nor deafen the ears. They operate quietly, often in their own enclosures which, when desirable, can be located above the confusion and safety hazards of surface traffic or in small tunnels—out of sight and hearing. See Figure 1.21. Furthermore, they do not contaminate the air with dust or hydrocarbons. At transfers, dust can be contained within transfer chutes or collected with suitable equipment, if necessary. Finally, overland belt conveyor systems can be designed to blend into the landscape, resulting in an unscarred, quiet, and pollution-free operation.

3.2.4 Low Maintenance Costs

Maintenance costs for belt conveyors are extremely low compared with most other means of transporting bulk materials. Extensive support systems, such as those commonly associated with truck haulage, are not required. Component parts are usually housed and have very long life compared with that of motor vehicles. Usually, they need only scheduled inspection and lubrication. Any repairs or replacements can be anticipated and unscheduled downtime avoided. Parts are small and accessible so replacements can be made on the site quickly and with minimal service equipment. Also, adequate inventories of spare parts can be maintained at a low cost and require relatively little storage space.

3.2.5 Conveyor System Parts

1) Conveyor Belts

Today there are different types of conveyor belts that have been created for conveying different kinds of material available in PVC and rubber materials. The belt consists of one or more layers of material. Many belts in general material handling have two layers. An under layer of material to provide linear strength and shape called a carcass and an over layer called the cover. The carcass is often a woven fabric having a warp & weft. The most common carcass materials are polyester, nylon and cotton. The cover is often various rubber or plastic compounds specified by use of the belt. Covers can be made from more exotic materials for unusual applications such as silicone for heat or gum rubber when traction is essential. A conveyor belt can be a slide and be controlled by the force of gravity.

Material flowing over the belt may be weighed in transit using a beltweigher. Belts with regularly spaced partitions, known as elevator belts, are used for transporting loose materials up steep inclines. Belt Conveyors are used in selfunloading bulk freighters and in live bottom trucks. Belt conveyor technology is also used in conveyor transport such as moving sidewalks or escalators, as well as on many manufacturing assembly lines. Stores often have conveyor belts at the check-out counter to move shopping items. Ski areas also use conveyor belts to transport skiers up the hill.

2) Pulleys

A conveyor pulley is a mechanical device used to change the direction of the belt in a conveyor system, to drive the belt, and to tension the belt. Conveyor pulleys are designed for use on belt conveyor systems as a means to drive, redirect, provide tension to, or help track the conveyor belt. Conveyor pulleys are not designed for the same application intent as conveyor rollers. Conveyor rollers are designed to be used in the bed of a conveyor as a support for the conveyed product and often under the conveyor bed in the return section to support the return side of the conveyor belt.

2 Conveyor design

Conveying of a variety of materials

The size of materials that can be conveyed is limited by the width of the belt. Materials can range from very fine, dusty chemicals to large, lumpy ore, stone, coal or pulpwood logs. Closely sized or friable materials are carried with minimum degradation. Because rubber belts are highly resistant to corrosion and abrasion, maintenance costs are comparatively low when handling highly corrosive materials or those that are extremely abrasive, such as alumina and sinter. Materials that might cause sticking or packing if transported by other means are often handled successfully on belt conveyors. Even such hot materials as foundry shakeout sand, coke, sinter, and iron ore pellets are conveyed successfully.

Troughed conveyor belt

The biggest cross sectional area of belt conveyor with three-idler set assuming that the values of surcharge angle, conveyor belt width, troughing angle and length dimensions of idlers.

Also it depends on usable conveyor belt width b which is the function of conveyor belt width B, moreover on the trough shape, i.e. on the number of idlers and their proportions (centre idler length l_3 and troughing angle λ [deg]), and on spherical cap shape of the cross-sectional area, which is limited by parabolic curve. This parabolic curve is characterized by surcharge angle θ [deg] of the conveying material.

If the value of surcharge angle θ [deg] of conveying material is known as well as conveyor belt width B, it is possible to express useable conveyor belt width b.

) Types of pulleys

Drive/Head Pulley:-

A conveyor pulley used for the purpose of driving a conveyor belt, Typically mounted in external bearings and driven by an external drive source.

Idler Pulley:-

Any pulley used in a non drive position that is intended to rotate freely and be driven by the belt

Return/Tail Pulley:-

A conveyor pulley used for the purpose of redirecting a conveyor belt back to the drive pulley. Tail pulleys can utilize internal bearings or can be mounted in external bearings and are typically located at the end of the conveyor bed. Tail pulleys commonly serve the purpose of a Take - Up pulley on conveyors of shorter lengths.

Snub Pulley:-

A conveyor pulley used to increase belt wrap around a drive pulley, typically for the purpose of improving traction.

Take - Up Pulley:-

A conveyor pulley used to remove slack and provide tension to a conveyor belt

Take - Up pulleys are more common to conveyors of longer lengths

Bend Pulley:-

A conveyor pulley used to redirect the belt and provide belt tension where bends occur in the conveyor system.

Conveyor Roller:-

A product used either in the bed of a conveyor as a support for the conveyed product or in the return section under the conveyor bed as a support for the conveyor belt.

III.DESIGN & CALCULATION

Troughed conveyor belt for conveying material from hopper to vibrating screen

b = 0,9. B - 0,05 for B 2 m

b = B - 0,25 for B > 2 m

Table 4.1 characteristic of Material sand bank, dry

Material	Average Bulk density	Angle of repose	Angle of inclination
Sand bank dry	1440-1760	35	15-18

Table 4.1 characteristic of Material sand bank, dry

Specific density = 1600 kg/m^3

= 1.6 t/m^3

Belt width, B = 800 mm

Troughing angle, $\lambda = 20°$

Surcharge angle, $\theta = 17°$

Useable conveyor belt width, b = 0.9 (B) – 0.05

=719.95 mm

= 720 mm (approx)

$l_3 = 400$ mm

X = (B-b)/2

= 40 mm

Z = 200 – X

= 160 mm

$z_1 = z \cos \lambda = 160 \cos 20$

= 150.35 mm

$b_1 = l_3 + (2 \times z_1)$

$= 400 + (2 \times 150.35)$

= 700.70mm

Area of the segment AED $S1 = 1/2 \left(\frac{2 Z \cos \lambda + l_3}{2 \sin \theta}\right)^2 \left(\frac{2\pi\theta}{180} - \sin 2\theta\right)$

The area of trapezium $S2 = z \sin \lambda \, (l_3 + z \cos \lambda)$

Total area of the load S = Area of the segment AED S1 + The area of trapezium S2

$S = 1/2 \left(\frac{2 Z \cos(\lambda + l_3)}{2 \sin \theta}\right)^2 \left(\frac{2\pi\theta}{180} - \sin 2\theta\right) + z \sin \lambda \, (l_3 + z \cos\lambda)$

$= 0.0547\ m^2$

Volume from hopper = 19 kg/s

$= 0.01186875\ m^3/s$

Length of conveyor required to occupy the volume of material falling on the belt from the hopper

L = (volume from hopper)/(Cross sectional area of belt)

= 0.01186835/0.0547

= 0.3 m

Speed of belt > 0.3 m/s

Time required for material to travel from one end to other end = 11.6/0.3 = 38.667 sec

Number of batches falling on the belt from the hopper = 15/0.01186875 = 1263.82 batches

Also time required for emptying the hopper is 1263.82 sec = 21.06 min

Time required by conveyor to carry $15 m^3$ of material from one end to other end is 21.06 + 0.38 = 21.44 min

AS the conveyor carries 15 m^3 of volume of material in 21.44min

Capacity is 42 m^3/hr = 67.35 t/hr

Belt width = 800mm

Belt speed = 1m/s

Distance between centres = 11.6m

Belt load = 67.35 t/hr

Angle of surcharge = 17°

Permissible belt speed for above value values is 2.75m/s

1m/s < 2.75 m/s

Table 4.2 - Maximum speeds advised

Lumpsize max. dimensions		**Belt dimensions min.width**	**max.speed**			
uniform up to mm	**mixed up to mm**	**mm**	**A**	**B**	**C**	**D**
125	200	650	3	2.75	2.38	2
170	300	800	3.5	3.2	2.75	2.35
250	400	1000	4	3.65	3.15	2.65

A - Light sliding material non abrasive, specific weight from 0.5 ÷ 1,0 t /m3

B - Material non abrasive, medium size, specific weight from 1.0 ÷ 1.5 t /m3

C - Material moderately abrasive and heavy with specific weight from 1.5 ÷ 2 t /m3

D - Abrasive material, heavy and sharp over 2 t /m3 specific weight

$I_m = I_v/\rho = 67.35/1.6 = 42\ m^3/hr$

$I_{vt} = I_m = 42\ m^3/hr$

Permissible $I_{vt} = 244\ m^3/hr > 42\ m^3/hr$

Table 4.3 - Loaded volume with 3 roll troughing sets v = 1 m/s

Belt width mm	**Angle of surcharge**	**IVT m³/h**				
		λ= 20°	λ= 25°	λ=30°	λ=35°	λ=40°
800	5°	139.6	162.0	182.1	198.3	227.1
	10°	173.6	194.4	212.7	226.8	252.0
	20°	244.0	262.8	278.2	290.1	306.0
	25°	275.0	299.1	313.2	322.9	334.8
	30°	324.0	339.4	352.4	359.2	367.9

Tangential force

$f_v = [L \times c_q \times c_t \times f (2 q_b + q_G + q_{RV} + q_{RO}) + (q_G \times H)]$

L = 11.6 m

$c_q = 4.292$

Table 4.4. - Coefficient of passive resistance given by temperature

Temperature °C	+20	+10	0	-10	-20	30
Factor Ct	1	1.01	1.04	1.10	1.16	1.27

$c_t = 1$

Table 4.5 - Coefficient of internal friction f

Horizontal belt conveyor rising and gently falling	Speed m/s					
	1	2	3	4	5	6
Rotating parts and material with standard internal friction	0.0160	0.0165	0.0170	0.0180	0.0200	0.0220

f = 0.0160

q_b = for breaking force 315 with (4+2) conveyor & core = 3

$q_G = I_v / 3.6 \times V = 18.70$ kg/m

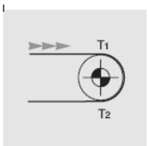
$q_{RO} = p_{prs}/q_o = 10.4/1.35 = 7.7$

Table 4.6 - Weight of rotating parts of the rollers (upper/lower)

Belt width mm	Roller diameter ,mm			
	89		108	
	p_{prs}	p_{pri}	p_{prs}	p_{pri}
800	10.4	7.8	16.0	11.4
1000	11.7	9.1	17.8	13.3

$q_{Ru} = p_{pri}/a_u$
$q_{Ru} = 7.8/3 = 2.6$
$a_u = 3m$
$f_v = 847.29$ N
$f_v = T_1 - T_2$
$T_1/T_2 = e^{\mu\theta}$
$T_2 = f_v/(e^{\mu\theta}-1)$
$= f_v \times c_w$

Table 4.7 - Wrap factor Cw

Drive arrangement	Angle of wrap	tension unit or counterweight pulley		screw tension unit pulley	
		unlagged	lagged	unlagged	lagged
	180°	0.84	0.50	1.2	0.8

Where $c_w = 0.5$
$T_2 = 423.64$ N
$T_1 = f_v + T_2$
$= 1270.93$ N
$T_u \max = T_1 + f_s/w$
$f_s = 10$
$= 1270.93 \times 10/800$
$= 15$ N/mm
Power rating of motor
$P = f_v \times (V/1000) \times \eta$
$f_v = 847.39$ N
V= 1m/s
η = gear train efficiency
= 85 %
P = 0.72 kw
P= 0.965 HP
P = 1HP
Minimum power required by the motor is 1HP without considering the loss
Roller diameter= 89mm
Roller pitch for upper roll = 1.35m
For lower roll = 3m

Table 4.8 - Maximum advised pitch of troughing sets

Belt width	Pitch of sets upper specific weight of conveyed material t/m³			lower
	< 1.2 m	1.2 m ÷ 2.0 m	> 2.0 m	
800	1.50	1.35	1.25	3.0
1000	1.35	1.20	1.10	3.0

Belt breaking load = 10 × working load
= 10 × 15
= 150 N/mm
Selecting belt with breaking load = 200 N/mm the minimum pulley diameter 200mm for motorised pulley & 160mm for rotor pulley

Table 4.9 -Minimum pulley diameters recommended

belt breaking l load N/mm	belt with textile core EP DIN 22102		
	Ø motorised pulley mm	return pulley	direction change
200	200	160	125
250	250	200	160

D= 320mm
For idler pulley

Table 4.11 Series CUF idler with incorporated bearings

Belt Width	Pulley type	D	B	d	d1	F	G	C	Weight Kg
800	CUF	320	950	40	38	30	1210	1270	75

D= 320mm
Pulley drive design for conveyor belt system
1) Diameter of pulley

$$\frac{N_1}{N_2} = \frac{D}{d} = G$$

Where G = gear ratio or speed ratio
N_1 = gearbox output shaft speed
N_2 =Driver shaft speed
D = large pulley diameter
d = small pulley diameter

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from equation

$\frac{225}{60} = \frac{D}{d} = 3.75$

D = 3.75d

Selecting D from standard pulley diameter

D = 400 mm

d = 112mm

2) Design power =

$$\frac{\text{Rated kw power} \times \text{load correction factor}}{\text{Arc of content factor} \times \text{small pulley diameter}}$$

$$= \frac{1.268 \times 1.2}{1.08 \times 0.5}$$

Design power = 2.8182 Kw

3) Belt width = $\frac{\text{Design power}}{\text{No.of plies} \times \text{load rating}}$

No. Of plies =2

Belt width = 25mm

4) Pulley width = Belt width + additional width

= 25 + 13 = 38 mm

5) length of belt

Centre distance = 700 mm

$$L = 2C + \frac{\pi}{2}(D + d) + \frac{(D-d)^2}{4} \times C$$

= 2233.46

= 2234mm

6) Belt tension calculation

Power = $(T_1 - T_2)$ V 1

Power = 1007.1W

$V = \frac{\pi d N_1}{60} = 1.88$ 2

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

$\mu = 0.35$

$\theta = 2.8$ rad

$\frac{T_1}{T_2} = 2.66$

$T_1 = 2.66T_2$ 3

From equation 1,2& 3

$1007.1 = (2.66T_2 - T_1) \times 1.88$

$T_2 = 322.7$ N

$T_1 = 858.39$N

Resultant tension $T_{eff} = 535.69$ N

Conveyor support structure design

Failure under buckling:-

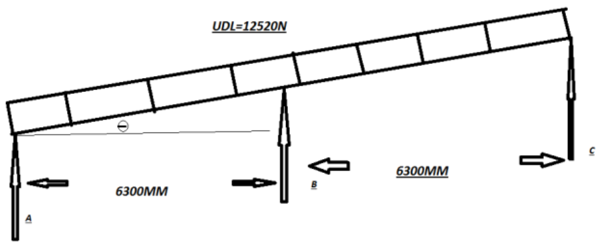


Fig no.4.1 Failure under buckling

$$\text{Load} \times \text{f.o.s.} = \frac{4 \times \pi^2 \times E \times I}{\left(\frac{le}{2}\right)^2}$$

Reaction on middle column = 6260N

FOS = 3

L = 2140 mm

P = 3 × 6260 = 18780

Structure should carry load of 18800 N buckling load capacity for both end

Select section = (40 × 40× 4) mm

$$\text{R.H.S.} = \frac{4 \times \pi^2 \times 5.54 \times 10^3 \times 11.07 \times 10^4}{\left(\frac{2140}{2}\right)^2}$$

= 21147.03 N > 18780

Hence square section (40 × 40× 4) mm selected

Failure under bending :-

Standard I – section (152 × 7.9) is selected for supporting conveyor components.

Material used is M.S. which has S_{yt} of 250 Mpa ,

Hence allowable stress , σ_{all} = 250 Mpa

Checking under bending

$\sigma_{bending} = \frac{M \times Y}{I}$

$I = (I_1 + A_1Y_1) + (I_2 + A_2Y_2) + (I_3 + A_3Y_3)$

$= 7.613 \times 10^6 \text{ mm}^4$

$M = P \times L = 6260 \times 3276.95$

$= 20.513 \times 10^{6}$ N-mm

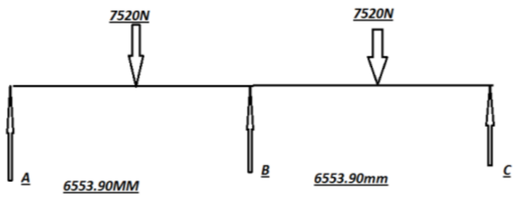


Fig 4.2 Bending movement diagram of conveyor support

$Y = b/2 = 152/2$

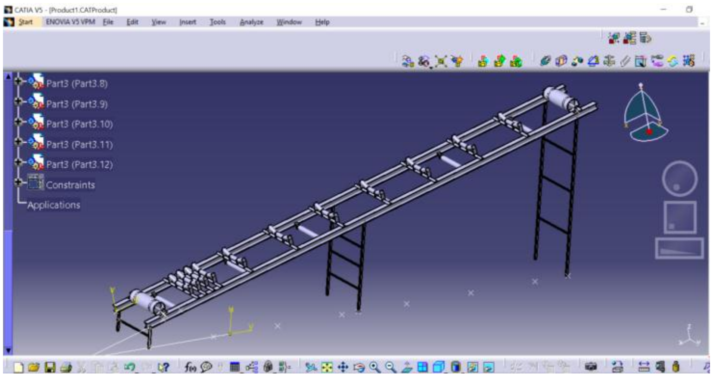
$= 76$mm

$$\sigma_{bending} = \frac{20.513\text{x}10^{6} \times 76}{7.613 \text{ x}10^{6}}$$

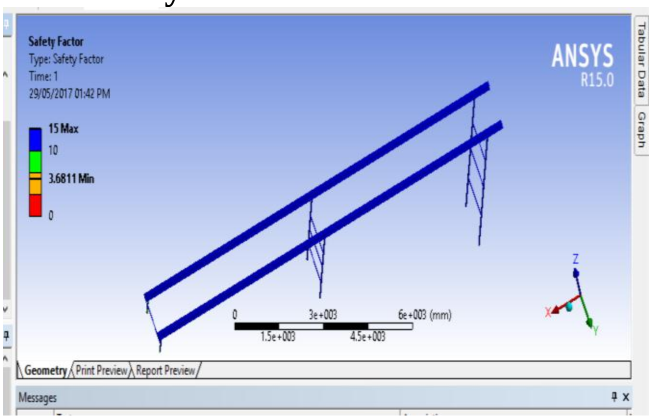
$= 204.6$ Mpa $< S_{YT}$

Hence design is safe under bending .

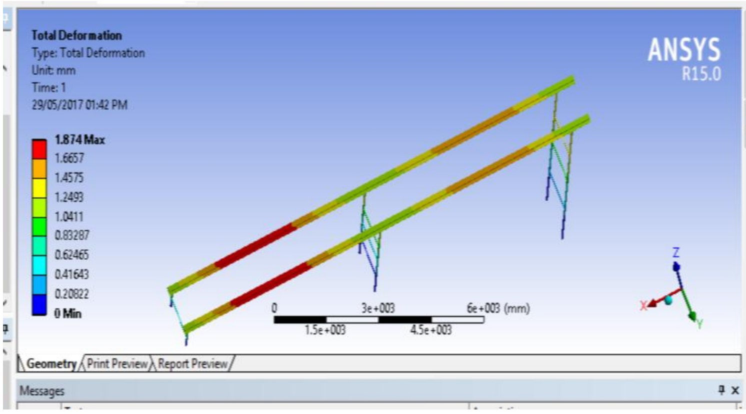
Cad model



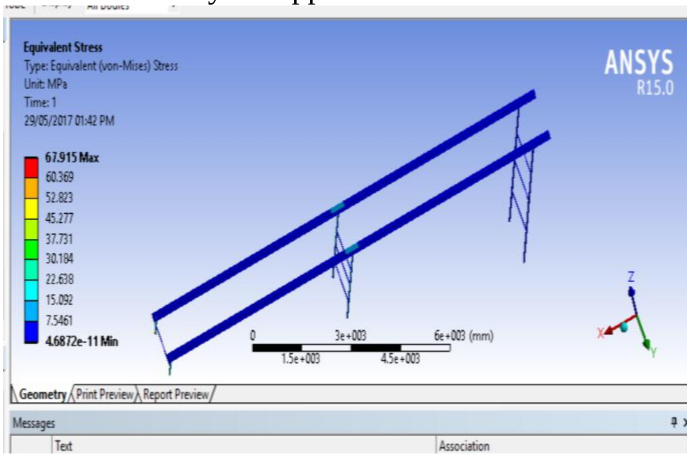
FEA Analysis



conveyor Support safety factor



conveyor Support deformation



Conveyor Support stress

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