3.2 Belts

Belts, ropes, chains, and other similar elastic or flexible machine elements are used in conveying systems and in the transmission of power over comparatively long distances. It often happens that these elements can be used as a replacement for gears, shafts, bearings, and other relatively rigid power-transmission devices. In many cases their use simplifies the design of a machine and substantially reduces the cost. In addition, since these elements are elastic and usually quite long, they play an important part in absorbing shock loads and in damping out and isolating the effects[1].

In order to design a belt drive, a belt has to be selected from the manufacturer's catalogue. For the selection of a proper belt for a given application, the following information is required.

- Power to be transmitted
- Input and output speeds
- Type of load

Our application uses a flat belt drive in which the dimensions are a constraint (width of belt). Thus, the output power is determined instead.

3.3 Pulleys

A pulley is a wheel on an axle that is designed to support movement and change of direction of a cable or belt along its circumference. Pulleys are used in a variety of ways to lift loads, apply forces, and to transmit power. In nautical contexts and conveyors. A pulley is also called a sheave or drum. Pulleys used in this conveyor change the direction of the belt on the conveyor as well transmit the mounted two-wheeler on the conveyor from ground into the trailer and vice a versa. The pulleys also act as a tension between the conveyor belt so as to keep it without any slag. As a rotating element in conveyor, driven pullies are often given the motion by means of rope, belt drive or motor. The means of pulley rotation in this system is a motor.

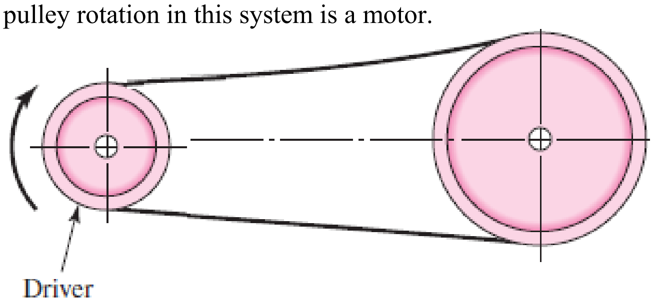


Figure 2: Standard belt drive

In our case, both the driver and driven pulleys are taken to be of the same diameter.

4. Idlers and Return Idlers

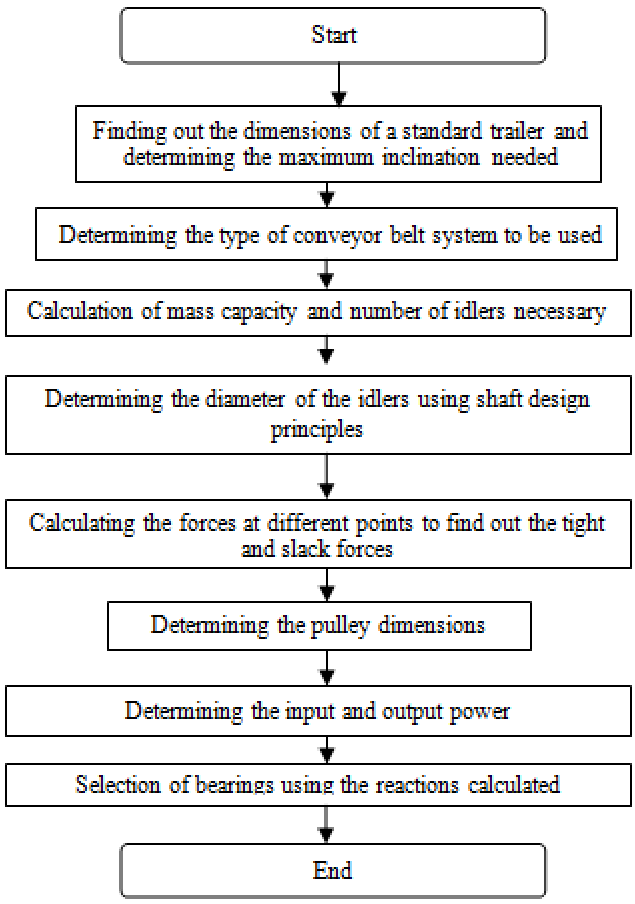
A conveyor idler is a small round part of a conveyor belt that is similar to a gear or pulley. Pulleys and idlers are very similar items. In general, the idler is designated as a pulley that does not bear a primary load, or primarily drive a motor or component of a conveyor system. Generally, a conveyor idler serves to help move the belt along, or provides specific amounts of resistance within a belt and pulley structure. Idlers can also help with gear ratio and other engineering aspects of a conveyor belt system. In some cases, conveyor idler models may have belt tensioner features, where moving the idler can change the tension on the belt.

Three idlers are used during the loading cycle. These are similar to shafts and are placed in bearings in which they rotate. The diameter of the idler is decided by the load due to the two wheelers. The three idlers are located at a distance of 1m from each other. The return idler is used primarily to avoid slacking of belt as it travels back to the driving pulley. The return idler only has to support the weight of the belt.

4.1 Bearings

All the idlers are supported by bearings. The bearings provide a seating for the idlers and prevent the movement of the assembly. The force that acts on these idlers is transmitted to the bearings. The bearings are selected from the standard SKF catalogue. In our case, the rotating speed is less although the torque is more. Since our there won't be any axial forces in our application, standard single row deep grove ball bearings are used. Depending on the force and the number of hours the bearing is expected to last, a suitable bearing is selected using the procedure for bearing design, which is described later.

5. Flow Chart of the entire design process



Considering standard trailer dimensions[4],

OVERALL			INTERIOR			REAR SWING DOOR		CAPACITY	TARE
Length	Width	Height	Length	Width	Height	Width	Height	(volume)	
53' Wedge	102"	13' 6"	52' 6"	98.5"	Front 108" Rear 110"	98"	110"	3,914 cu ft	14,400 lbs

The blue line in the diagram represents the door which is acting as an inclined plane for loading the vehicles. The red line represents the inclination needed to transfer vehicles to the second floor.

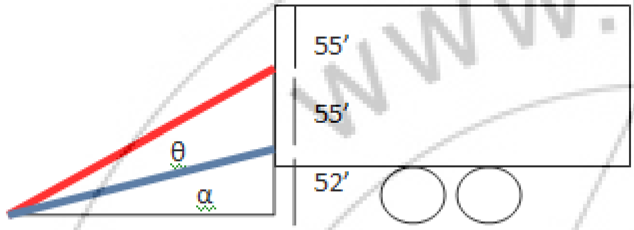


Figure 3: Trailer loading condition

$\sin \alpha = 52'/110'$

$\alpha = 28.211^0$

$l = 110 \times \cos 28.211$

$= 96.93'$

$\tan \theta = 107'/96.93$

$\theta = 47.83^0$

Our actual conveyor belt diagram as per the solid model prepared on CATIA would look like this

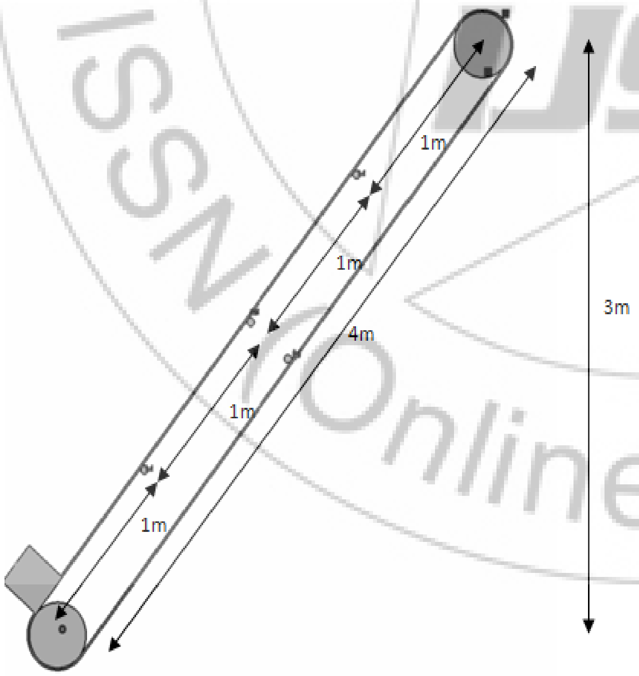


Figure 4: Conveyor belt system dimensions

Capacity of inclined belt conveyor

Weight of vehicle assumed=250kg

Mass capacity of belt

M= (m x Time taken by conveyor to complete one revolution)

= 250 x (Number of minutes/Time for one revolution) x 60

= 250 x 60/4 x 60

= 225×10^3 kg/hr

After considering the dimensions of standard vehicles, the width of the belt was assumed to be 350mm. The next standard conveyor belt width of 400mm was chosen. Velocity of belt was assumed to be 1m/s. The following parameters related to conveyor belt design were determined.

1) Capacity of inclined belt (Q)

$Q = kb^2V$ [5]

Where Q is the capacity of the belt in kg/hr,

b is the belt width

V is the velocity of belt

$Q = 2.5 \times 10^{-4} (0.9 \times 0.4 - 0.05)^2 \times 1$

$Q = 0.0865$kg/hr

2) Number of load carrying run idlers (Z_c)

$T_c = L/(Z_c+1)$

T_c=pitch of idlers= 1m

L=length of belt=4m

$1 = 4/(Z_c+1)$

$Z_c = 3$

3) Number of return run idlers (Z_r)

$T_r = L/(1+Z_r)$

T_r = pitch = 2m

$2 = 4/(1+Z_r)$

$Z_r = 1$

4) Idler (shaft) Design

The weight of the vehicle during the loading cycle is supported by the load carrying idlers. At any given point of time, the vehicle would be supported by two idlers or an idler and a pulley. Hence the load acting on the idler at any point is half the weight of the vehicle.

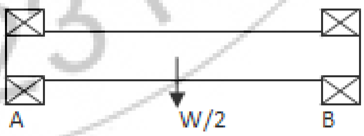


Figure 5: Load acting on idlers

The idlers are similar to simply supported shafts with bearings at both ends.

Balancing out the vertical forces,

$V_a + V_b = W/2$

Since the weight is acting on the centre,

$V_a = V_b$

Hence, $V_a = W/4 = 250 \times 9.81/4$

= 613.125N
Since the idlers do not transmit any torque, only the bending moment needs to be considered for the shaft design.

Max. Moment (M)= W/2 x L_s/2
Length of idler=width of belt=400mm
Using ASME shaft design procedure[6],
$T_e = \text{sqrt}\{(K_b M)^2+(K_t T)^2\}$

Considering heavy load with shock, K_b=2, K_t=1.5
Since T=0,
$T_e = K_b$ x M
T_e = 490.5 x 10^3 N-mm

By maximum shear stress theory,
T = $16T_e/\pi d^3$
Assuming idler to be of MS,
85.5=16 x 490.5 x $10^3/\pi d^3$
d=30.799=35mm (standard shaft diameter)

5) Load resistance due to lifting of material
$F_m = M_m$ x g x h
F_m = 250/4 x 9.81 x 3
F_m = 1839.64 N

Belt tensions along conveyor\
At initial point I,
$F_i=F_{slack}$

At point 1
Frictional resistance due to return idler
Mr=mass of return idler=11kg
L=4m
F_c = 0.035
M_b= 2kg/m

$F_1= F_{slack} + \{F_c (M_b +M_r\times Z_r/L) g L\}$
$F_1= F_{slack}$ + 6.523N

At point 2
$F_2= F_1 (1 + \epsilon p1)$

ϵp1= snub factor for tail pulley
ϵp1= 0.06 (as per catalogue)

$F_2= F_{slack}$ + 6.523 (1.06)
F_2= 1.06 F_{slack} +7 N

At point 3
M_c= 11kg
F_c= 0.035
M_m= 0.2

$F_3= F_2 + \{F_c(M_b + M_m +Z_m M_c/L) g L\}$
$F_3= F_2$ +{ 0.035 (2 +62.5+3 x 11/4) 9.81 x 4}
F_3= 1.06 F_{slack} +7 + 100
F_3= 1.06F_{slack} + 107N

At point 4 (final point)

$F_4= (1+ \epsilon p2) F_3$
ϵp2= snub factor for drive pulley
ϵp2= 0.06

F_4= 1.06 (1.06 Fslack +107)
F_{tight}= 1.1236 F_{slack} +113.42 N

6) Ratio of effective belt tensions on drive pulley
ϴ= arc of contact
= 210^0
= 210/180 x π
= 3.665 rad
μ= coefficient of friction between belt and pulley
= 0.4
$F_{tight}/F_{slack} = e^{\mu\Theta}$
$F_{tight}/F_{slack}=e^{0.4 \times 3.665}$ =4.332
F_{tight}=4.332 F_{slack}
4.332F_{slack}=1.123 F_{slack} + 113.42 + 1839.64
F_{slack}=608N
F_{tight}=2634N

7) Drive and Tail Pulleys
Pulley minimum diameter (D_{min}) = K_1 x K_2 x Z_p [5]
K_1= material factor for plies
=2 for capron belt
K_2= belt tension arc of contact factor =57
Z_p=number of plies =3

D_{min}=2 x 57 x 3 =342mm

Pulley Length
L_p= B + 2S
= 400 + 2 x 60
= 520mm

S is the side margin (This is taken as minimum as possible to position the vehicle perfectly.)

Power required for drive pulley

$P_o= (F_{tight} - F_{slack})$ x V/1000
= (2634-608) x 1/1000
= 2.025 KW

Input power to belt

$P_i=P_o$/efficiency

Assuming efficiency to be 93%,

P_i=2.251kW

Power in HP=2.251 x 10^3/746
= 3.017HP

8) Bearing Design
There is no axial force acting on the bearings. All the forces are radial.
Considering single row deep grove ball bearings,
d=35mm,

Taking the bearing with designation 61807[3],
C_0=3000, C=4030

Where C_0 is the static load capacity and C is the dynamic load capacity

Taking life of bearing to be 8000hours (intermittent operation),
L_{h10}=8000

L_{10}= 60 x L_{h10} xN/10^6
L_{10} is the life of bearing in million revolutions

= 60 x 8000 x 27.9/ 10^6
= 13.4 million revolutions

C= P $(L_{10})^{1/3}$
P is the net force acting on the bearing.

C=613.125 $(13.4)^{1/3}$
= 1456.39N

This is less than the dynamic capacity of the bearing selected. Hence our bearing design is complete.

7. Conclusion

1) The proposed system of material handling for transmitting two-wheelers in and out of trailer reduces labor cost and human efforts.
2) The system will ensure effective and seamless working.
3) The vehicles would be transferred with a higher efficiency and will reduce time considerably as well.
4) Though it appears that the designed system will have high installation cost, in long run it is cost saving as labor cost is increasing day by day.
5) The only human interference throughout working of this system is at the time of loading and unloading the vehicle on conveyor.
6) The same principle can be applied to motorbikes-they can be latched near the leg guard.

References

[1] Shigley, "Mechanical Engineering Design", pg 860
[2] http://en.wikipedia.org/wiki/Semi-trailer
[3] V B Bhandari, "Design of Machine Elements", pg 575
[4] http://www.wbmcguire.com/links/Guides/TruckTrailer Guide.pdf
[5] R B Patil, "Mechanical System Design" pg 7-30,7-31, 7-41,7-52
[6] R B Patil, "Machine Design I" pg1 1-9

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