D225 2005 Q9

The diagram shows a conveyor belt used for delivering parts along a production line. The belt runs over two motorised drums as shown with an average speed of 15 m/s. Each drum has an outside diameter of 200 mm and a moment of inertia of 0.3 kg m^2. The total mass of the belt is 15 kg. The upper span of the belt is supported on a smooth table and the coefficient of friction between the belt and the table is 0.1. When no object is present on the belt, the total friction force between the belt and table is 6 N.

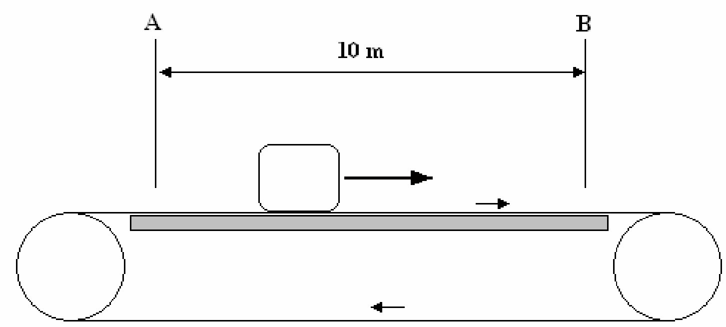
One part of mass 5 kg is dropped vertically onto the belt each second from a height of 600 mm at position A. and this is transported to position B where it is pushed sideways off the belt. Position B is 10 m from position A. While the part is being pushed off the belt, the forces acting on it are horizontal and perpendicular to the direction of motion of the belt.

a) Estimate the total energy loss in friction between the belt and the table each second. (Assume that the belt speed is 15 m/s).

b) Assuming that the belt is stiff and that the belt speed before a part drops onto it is 15.5 m/s; estimate the speed change of the system over the short time period between when the part first part touches the belt and when it is not slipping on the belt.

c) Determine the magnitude and direction of the average horizontal force (if any) needed to prevent the complete conveyor system from moving.

d) Determine a maximum mass of a part which could be dropped from onto this belt from a height of 600 mm without momentarily reducing its velocity to zero.



SOLUTION

The question takes a bit of digesting and assumptions need to be made. I think I must be missing something as what can be done seems too easy. I fail to see the purpose of the 600 mm height as this information might be needed to work out the force of impact with the belt and determine if it bounces but more data would be needed for that. If anyone can provide a better solution please contact me. admin@www.freestudy.co.uk

If the parts are dropped every second then they will transported approximately 15 m in that time so there can only be one part on the belt at any time.

Part a)

It's not clear whether this is for the belt only or for the belt with a part on it.

Power loss to friction = Force x velocity = 6 x 15 = 90 Watts.

When it is transporting a part at constant speed the friction force is increased by the extra weight on the belt such that $F = \mu Mg = 0.1 \times 5 \times 9.81 = 4.905$ N

This is added to the initial friction force of 6 N.

F = 10.905 N

Power loss to friction = Force x velocity = 10.905 x 15 = 163.575 Watts.

Part b)

Use the impulse - momentum equation $F\,\Delta t = M\,\Delta v$

The box that has dropped will initially skid until it is accelerated to the same velocity as the belt.

$F\,\Delta t = M_{part}\,\Delta v = 5\,(v - 0) = 5v$ where v is the final velocity of part and belt.

For a belt initially with nothing on it, the same force will cause a change in the momentum of the belt and drums.

$$F\,\Delta t = M_{belt}\Delta v + \frac{2\,(I\,\Delta\omega)}{r} \quad \text{r is the drum radius and } \omega = v/r$$

$$F\,\Delta t = 15\Delta v + 2\,I\,\frac{\Delta v}{r^2} = 15(15.5 - v) + 2\,(0.3)\,\frac{(15.5 - v)}{0.1^2}$$

$$F\,\Delta t = 15(15.5 - v) + 60\,(15.5 - v) = 75\,(15.5 - v)$$

The impulse is the same for both so we can equate.

$$5(v - 0) = 75\,(15.5 - v) = 1162.5 - 75v$$

$$80v = 1162.5 \qquad v = 14.531\ \text{m/s}$$

The change is speed is 14.531– 15.5 = -0.969 m/s

Since the drums are motorised, they would add momentum to the system during this period, the above would only apply to a free running system in which momentum is conserved.

Part c)

I find this part puzzling. The maximum force needed to stop the belt depends on how large a force the motors are able to produce and there is no way to know this.

When it is transporting a part at constant speed the friction force is 10.905 N

This would be the minimum force required to move the belt.

d)

From part b) we had:

$F\,\Delta t = M_{part}\,\Delta v$

$$F\,\Delta t = 15\Delta v + 2\,I\,\frac{\Delta v}{r^2} = 15(15.5 - v) + 2\,(0.3)\,\frac{(15.5 - v)}{0.1^2}$$

$$\text{Equating } M_{part}v = 15(15.5 - v) + 2\,(0.3)\,\frac{(15.5 - v)}{0.1^2}$$

The only way v can be reduced to zero is when the mass is infinite.