Protecting Your Tail Pulley

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1. Background

Tail pulleys are a vital component of a belt conveyor system. This component is subjected to danger whenever any piece of material falls onto the return side of the conveyor belt.

Occasionally along its return run, the belt will collect and carry a lump of spilled material to the tail pulley on the non-carrying side of the belt. If these objects are not removed from the belt, they can become trapped between the pulley and the belt and damage either or both.

The entrapment of anything between the belt and the pulley can do significant damage to a conveyor system **(See Figure 1.1)**.

Figure 1.1 Tail Pulley Suffering From Entrapment.

When fugitive material is trapped between the belt and the pulley, one or more failures are likely to occur:

A. *Degradation of the Fugitive Material*

If the material fails, it will break up into smaller parts and be carried between the belt and the pulley. Material trapped in this location can allow the belt to slip against the pulley, causing the non-carrying underside of the belt to wear. Even small particles and fines can wear and grind away on the less durable, more easily damaged inside surface of the belt. Furthermore, material that builds up on tail pulleys will cause belt wander that in turn can damage the belt edge and/or the conveyor structure.

B. *Failure of the Belt*

Any material entrapped between the pulley and the belt has the potential for forcing its way out through the top cover of the belt, particularly if the material is a lump with sharp edges. This material creates an uneven belt surface and can be a starting point for longitudinal and profile rips, holes, or edge gouges along the length of the belt.

C. *Failure of the Pulley*

If the material and the belt do not fail, the face of the tail pulley is likely to be damaged. A damaged pulley will lead to belt misalignment, belt damage or pulley slippage.

The most damaging problem arising from the entrapment of material between the belt and tail pulley is the fact that it can become a repeating phenomenon. Once a piece of material reaches the pulley, it can be pinched between the belt and pulley, carried around the pulley's rotation, and then ejected back onto the return side of the belt. Once there, it will again travel toward the pulley to be consumed again (**see Figure 1.2**).

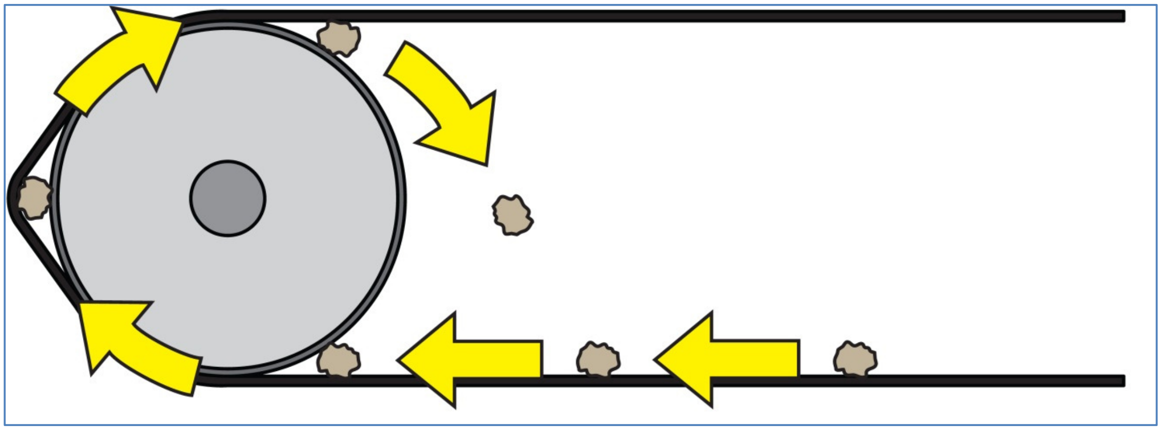

Figure 1.2 Repeated Entrapments.

In essence, if it initially fails to break something, the lump will keep trying until a failure occurs or the lump is removed from the belt. If the material is strong enough, it could destroy the entire tail pulley section of a belt conveyor system.

This potential damage can be minimized with proper transfer design. But regardless of precautions, there is still the possibility that dislodged components or conveyed material will come in contact with the tail pulley. Consequently, there is a need for a system to prevent these items from damaging the conveyor's rolling components. An easily installed precaution against such danger is a pulley protection plow **(see figure 1.3)**.

Figure 1.3 (plow in application)

A pulley protection plow removes fugitive materials with a simple, low-pressure scraping that directs the material off the belt. The mission of a plow is to block any large lumps or stray conveyor components, such as idler rollers, belt-cleaner blades, or other tramp iron, from entering the tail pulley where they can damage the belt **(see Figure 1.4)**.

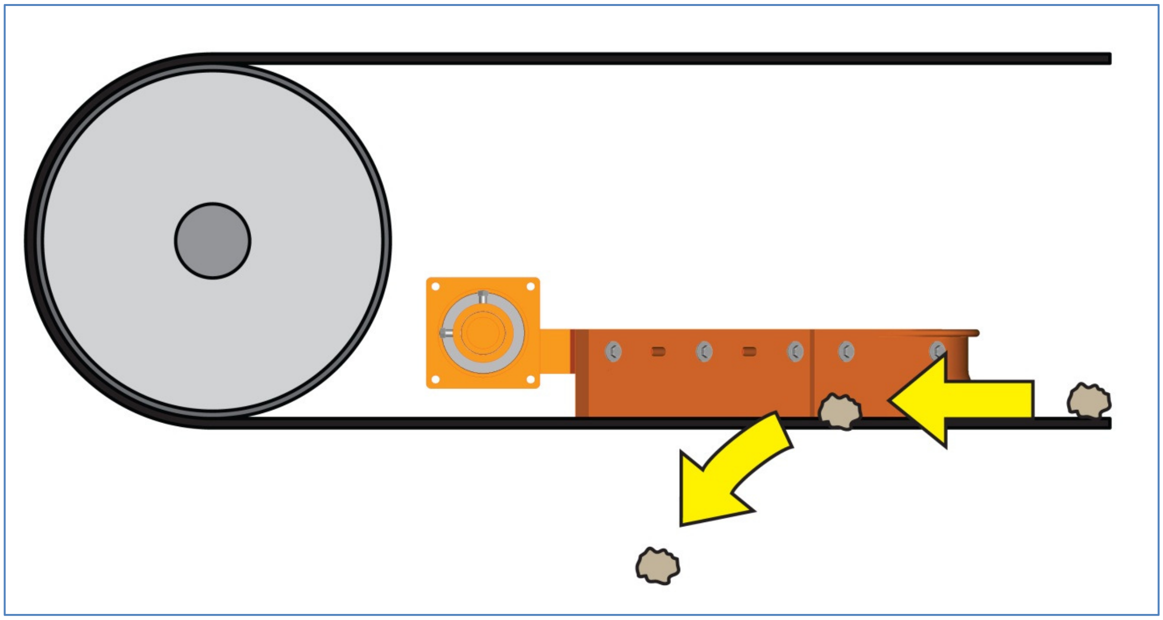

Figure 1.4 Plow Theory

Pulley protection plows are usually designed to float on the belt's surface, using either the weight of the plow or a tensioning mechanism to hold the plow with a slight pressure, 13 to 20 kilopascals (2 to 3 psi), against the belt. These plows are built of heavy-duty construction and tall enough to keep fast moving materials from going over the top of the plow.

While the need for a tail protection system is not in question, the strength of said system has been debated. Previously, no effort has been made to quantify the impact force that a tail pulley protection system needs to withstand.

In this paper I will attempt to define a methodology to quantify the impact force of a piece of fugitive material on the return run of the belt.

2. Procedure

Consider the situation depicted in **figure 2.1**. This is a representation of a body of material traveling on a conveyor belt at a constant velocity toward a rigid body.

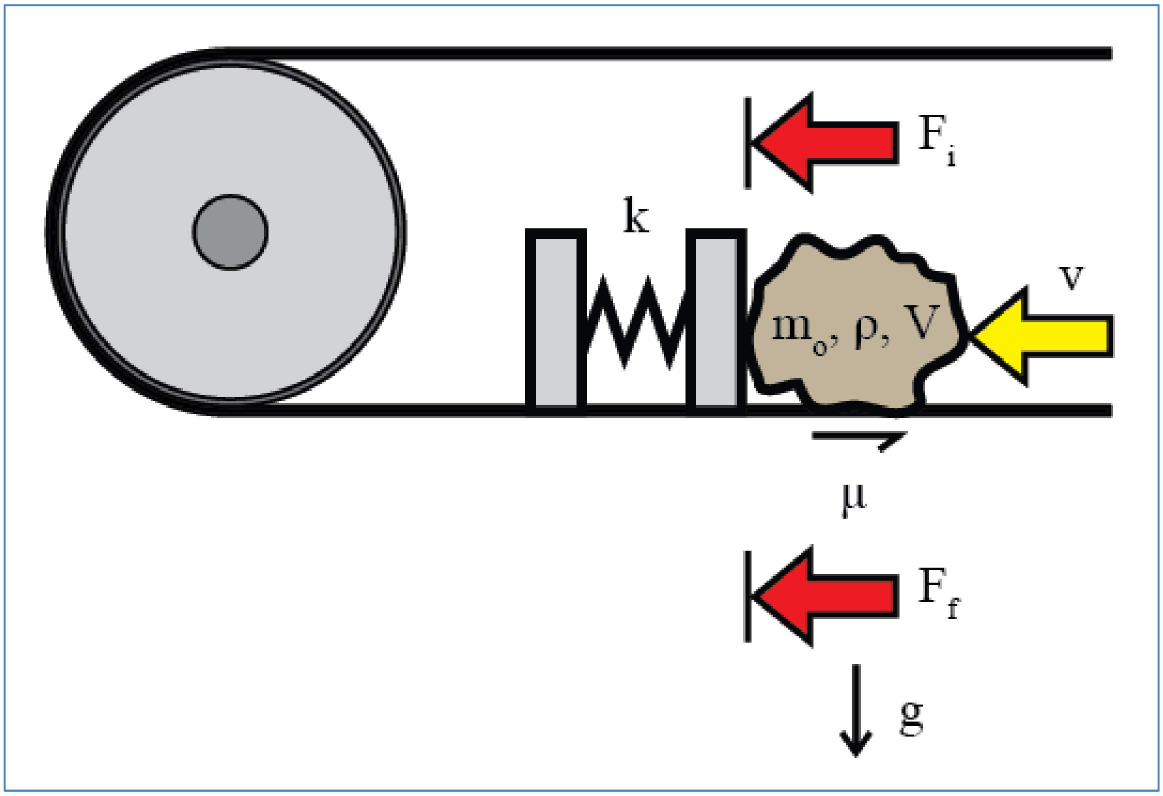

Figure 2.1 Free Body Diagram of Impact

Inputs

Velocity of lump before impact = v

Friction between the object and the conveyor belt = μ

Acceleration due to gravity = g

Spring rate of rigid body = k

Mass of object = m_o

Bulk density of material = ρ

Volume of largest lump of material = V

Unknowns

Impact force imparted to the body = F_i

Friction force imparted to the body = F_f

Total force imparted to the body = F_{total}

The impact force must be derived from conservation of energy.

$U_l = \frac{m_o v^2}{2}$ Kinetic energy of lump (1)

$U_b = \frac{ku^2}{2}$ Energy absorbed by body (2)

As all energy must be conserved, so equations (1) and (2) can be equated.

$\frac{m_o v^2}{2} = \frac{ku^2}{2}$ Energy Balance (3)

$m_o v^2 = ku^2$ (3) Simplified (4)

$F_i = ku$ Spring Law (5)

$u = \frac{F_i}{k}$ Isolate u in equation (5) (6)

$m_o v^2 = k\left(\frac{F_i}{k}\right)^2$ Substitute (6) into (4) (7)

$F_i = \sqrt{m_o v^2 k}$ Solve (7) for impact Force imparted to the body (8)

$F_i = v \cdot \sqrt{m_o k}$ (8) Simplified (9)

An additional force will be generated from friction as the conveyor belt slides under the now stationary object.

$$F_f = m_o g \mu \qquad \text{Friction force} \tag{10}$$

The total force imparted to the object will be the sum of the impact force and the friction force.

$$F_{total} = v \cdot \sqrt{m_o k} + m_o g \mu \tag{11}$$

Mass of the impacting body may not be conveniently measured. In such cases it is possible to approximate the mass with the following equation

$$m_o = \rho \cdot V \qquad \text{Mass of impacting body} \tag{12}$$

Equation (12) can be substituted into equation (11) to find the Total force imparted on a body from an impact and the friction of a conveyor belt.

$$F_{total} = v \cdot \sqrt{\rho \mathrm{V} k} + \rho V g \mu \tag{13}$$

3. Results

Example - Coal Lump Impacting a Tail Protection **Plow (Figure 3.1)**

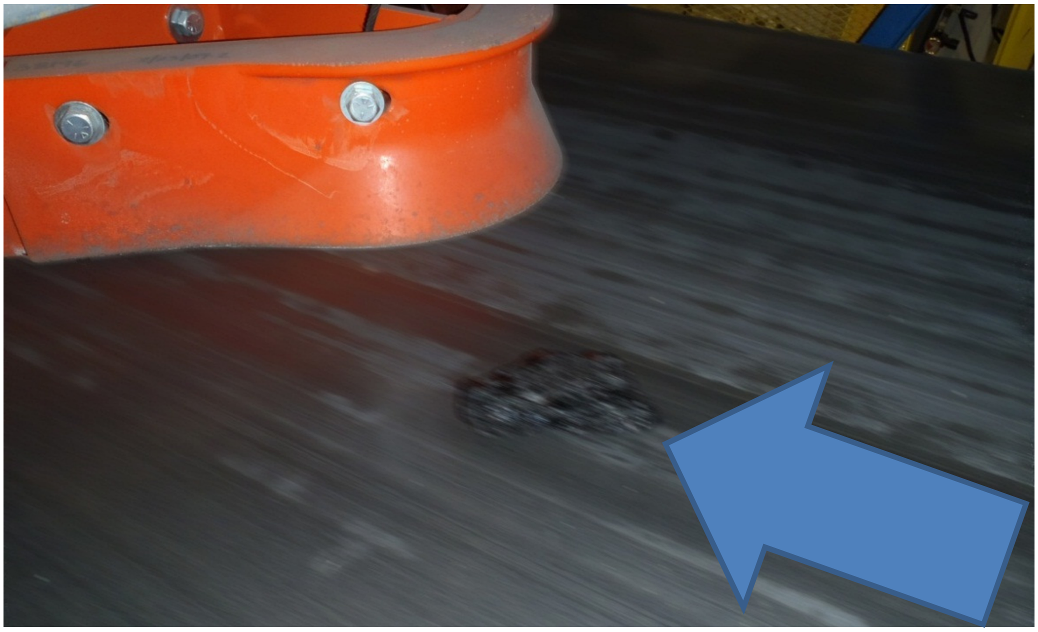

Figure 3.1 Lump of Coal Moving on Conveyor Belt.

Velocity of lump before impact = 3.75 m/s

Friction between the object and the conveyor belt = (assume worst case 1)

Acceleration due to gravity = 9.81 m/s²

Bulk density of material = 1000 kg/m³

Volume of largest lump of material = 0.2m x 0.2m x 0.2m

Spring rate of rigid body = $3x10^4$ N/m

From equation (13) the total force is found to be

$$F_{total} = 3.75 \cdot \sqrt{(1000)(0.008)(3x10^4)} + (1000)(0.008)(9.81)(1)$$

$$F_{total} = 1837 + 78 \text{ N}$$

$$F_{total} = 1915 \text{ N}$$

4. Discussion

This force can be used as a design load for structures, components, and fasteners with normal safety factors as though it were a static load.

In most cases, the frictional component of the total force is very small in comparison to the impact force. A detailed analysis would require this to be considered, but a conservative safety factor would compensate for the neglect of this factor.

The impact caused by a lump of material could be quite large if conditions such as high belt speed and large lumps are present. These large impacts must be considered as belt speeds increase worldwide

The only variable controllable by users is the spring constant of the component (k). As the spring constant value is lowered, the impact force is lowered. This occurs because the material is slowed to a stop over a greater interval of time. An example of this can be illustrated by dropping an egg onto a mattress as opposed to a concrete floor. Many factors must be considered in this factor such as geometry, material, orientation of loading, attachment points etc. Lower spring rate can be created by attaching a soft plastic or rubber to the impact area of the component, or placing a soft spring in the mounting of the component. As there is no single condition indicative of the loading and orientation of a rigid body in the bulk material industry, engineering judgment must be used.

The geometry of the tail protection plow also impacts the force. Given the resilience of the materials and the angle the material is deflected, the impact force may be reduced as the object will not come to a complete stop, but rather have its direction of travel changed. Again engineering judgment must be used in this situation.

5. Conclusion

The tail pulley of a belt conveyor needs to be protected from entrapment of material or stray conveyor components. This protection can be accomplished by the use of a tail protection plow. This plow must be designed to withstand the impacts of large pieces of material traveling along the return run of the belt. The plow must be designed to accommodate the increased belt speeds seen around the bulk solids industry. The plow must be elastic enough to maximize the stopping time of the material, but be rigid enough to accommodate the large forces that may be generated by these impacts.

These factors can be accounted for by a design engineer, or they could be calculated by a reputable firm manufacturing engineered systems to protect tail pulleys.

6. References

Swinderman, R. Todd, et. al. Pulley Protection Plows. Foundations, Fourth Edition. Ed. Andy Marti. Stevens Point, WI: Martin Engineering, 2009. 244-251.

Ojha, Rabindra Nath. "Impact Forces in Design of Material Handling Plants and Equipment." Bulk Solids Handling 13, No 2, May (1993): 330-334.