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Andrew Timmerman advises on accurately calculating conveyor belt sag between idlers to minimise spillage and dust at transfer points

Spillage in the loading zone of a belt conveyor can raise the cost of operation significantly both from an efficiency and safety standpoint. One of the main sources of spillage stems from the weight of the cargo causing the belt to sag creating gaps in-between idlers. Aided by air pressure in the transfer chute, dust and fines escape, resulting in fouled idler bearings and mechanical parts, causing them to fail and be replaced.

The spillage piles below the system and clutters walkways requiring additional workers to clean it up, raising the cost of labour and causing a possible workplace hazard. If not regularly addressed, the spilled material can encapsulate the belt and tail pulley, fouling the unprotected return side of the belt. By far the most expensive single component on any conveyor system, a belt with material adhered to the underside leads to abrasion damage, mistracking and slippage which increases the power requirements.

To avoid these consequences and mitigate belt sag, conveyor designers recommend constructing a sealed environment in the transfer chute: reducing the distance between idlers or adding cradles. Cradles are slick urethane pads on a rigid steel frame that produce an even belt path

$$\Delta Y_s = \frac{(W_b + W_m) \cdot S_i \cdot k}{T_m}$$

Given: A belt that weighs 550 newtons per meter (38 lb_f/ft) is carrying 3000 newtons per meter (205 lb_f/ft) of material. The idlers are spaced at 600 millimeters (2 ft) and the tension in the area is 24000 newtons (5400 lb_f). Find: The belt sag.

Variables		Metric Units	Imperial Units
ΔY_s	Belt Sag	millimeters	inches
W_b	Weight (Force) of the Belt per Length of Belt	550 N/m	38 lb_f/ft
W_m	Weight (Force) of the Material per Length of Belt	3000 N/m	205 lb_f/ft
S_i	Idler Spacing	600 mm	2 ft
T_m	Belt Tension	24000 N	5400 lb_f
k	Conversion Factor	0,038	1.5

Metric: $\Delta Y_s = \frac{(550 + 3000) \cdot 600 \cdot 0{,}038}{24000} = 3{,}37$

Imperial: $\Delta Y_s = \frac{(38 + 205) \cdot 2 \cdot 1.5}{5400} = 0.135$

ΔY_s	Belt Sag	3,37 mm	0.135 in.

FIGURE 1: Belt Sag Calculation

allowing the rubber skirting to form a tight seal along the entire length of the chute. Not only does the cradle/skirting combination eliminate gaps, it allows for greater airflow control through the loading, settling and stilling zone for superior dust and spillage suppression.

However, a tight seal can induce additional friction. Although field tests have shown minimal erosion of the belting or splice, it calls for slightly more power, the ongoing cost of which is no small concern to operators. This article provides the calculations required to determine the distance between idlers to reduce belt sag and will discuss how engineers can calculate the power requirements of a cradle system.

The data will help operators decide if installing preventive measures – such as modern conveyor transfer point sealing equipment like cradles and skirting – is more cost effective over the long run than reactive measures like cleanup and ongoing equipment replacement.

DETERMINING SAG AND IDLER DISTANCE

In the sixth edition of *Belt Conveyors for Bulk Materials*, the Conveyor Equipment Manufacturer's Association (CEMA) recommends that conveyor belt sag between idlers be limited to 2% for 35-degree idlers and 3% for 20-degree idlers. The CEMA method refers to limiting sag outside the load zone to prevent spillage.

To fully prevent spillage, dust, premature belt wear, wearliner depreciation, and skirt seal wear in the load zone, the sag must be significantly less than that recommended by CEMA. For example, using the CEMA method results in a recommended maximum sag between idlers of 12.5mm for 35° idlers and 19mm for 20° idlers. [Fig. 1] For loading zones with many gaps and tons of material escaping from the chute, field tests have shown that this is clearly unacceptable sag for control of fugitive materials in the load zone.

Sag (Ys) is proportional to the weight (force) of the belt and bulk material (Wb + Wm) [newtons (lbf)] and the idler spacing (SI) [mm], and it is inversely proportional to the minimum belt tension in the load zone (Tm) [newtons (lbf)]. [Fig. 1] To control fugitive materials, designers should consider managing the belt tension and idler spacing in the load zone to keep belt sag at no more than 3mm and preferably 0.0. Even with very little sag, if belt support is not continuous, fugitive materials can escape and cause wear.

The example in Figure 1 shows that, with idler spacing of 600mm, there is 3.37mm of sag. If the idler spacing in the example is reduced to 178mm, the belt sag drops to 1.0mm. On the other hand, if a belt-support system such as an impact cradle or air-supported conveyor section is used, idler spacing (SI) can be assumed to be 0.0. The calculation then yields belt sag of 0.0, because there should be no sag when the belt is a continuous, flat surface.

CRADLES AND POWER REQUIREMENTS

Belt-support systems have a significant effect on the power requirements of a conveyor. Changes in belt support will have a particularly noticeable effect on short or under-powered systems. Conveyor designers should ensure there is adequate conveyor drive power available to compensate for the additional friction placed on the conveyor when

$$\Delta T_s = (W_b \cdot L_b \cdot 0.1) + (F_{ss} \cdot 2 \cdot L_b)$$

Given: *A conveyor belt weighing 130 newtons per meter (9 lb_f/ft) is supported under the seal for 6 meters (20 ft). The seal presses on the belt with a force of 45 newtons per meter (3 lb_f/ft).* ***Find:*** *Tension added to the belt due to the sealing support.*

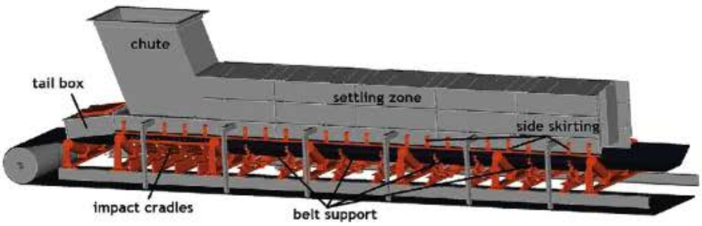
Variables		Metric Units	Imperial Units
ΔT_s	Tension Added to the Belt due to the Sealing Support	newtons	pounds-force
W_b	Weight (Force) of the Belt per Length of Belt	130 N/m	9 lb_f/ft
F_{ss}	Rubber Strip Sealing Load	45 N/m	3 lb_f/ft
L_b	Length Belt Support	6 m	20 ft

Metric: $\Delta T_s = (130 \cdot 6 \cdot 0{,}1) + (45 \cdot 2 \cdot 6) = 618$

Imperial: $\Delta T_s = (9 \cdot 20 \cdot 0.1) + (3 \cdot 2 \cdot 20) = 138$

ΔT_s	Tension Added to the Belt due to the Sealing Support	618 N	138 lb_f

FIGURE 2: Tension added to the belt due to sealing support



A well-designed chute structure provides a sealed environment to control spillage and offer enough space for dust to settle

$$\Delta T_{IB} = (W_b \cdot L_b) + (F_{ss} \cdot 2 \cdot L_b) + \left(\frac{Q \cdot L_b \cdot k}{V} \right)$$

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Given: *A conveyor belt weighing 130 newtons per meter (9 lb$_f$/ft) is supported by an impact bed for 1,5 meters (5 ft). The seal presses on the belt with a force of 45 newtons per meter (3 lb$_f$/ft). The belt carries 275 tons per hour (300 st/h) and travels at 1,25 meters per second (250 ft/min).* **Find:** *Tension added to the belt due to the impact bed.*

	Variables	Metric	Imperial
ΔT_{IB}	Tension Added to the Belt due to the Impact Bed	newtons	pounds-force
W_b	Weight (Force) of the Belt per Length of Belt	130 N/m	9 lb$_f$/ft
L_b	Length Belt Support	1,5 m	5 ft
F_{ss}	Rubber Strip Sealing Load	45 N/m	3 lb$_f$/ft
Q	Material Flow	275 t/h	300 st/h
V	Belt Speed	1,25 m/s	250 ft/min
k	Conversion Factor	2,725	33.33

Metric: $\Delta T_{IB} = (130 \cdot 1{,}5) + (45 \cdot 2 \cdot 1{,}5) + \left(\frac{275 \cdot 1{,}5 \cdot 2{,}725}{1{,}25} \right) = 1230$

Imperial: $\Delta T_{IB} = (9 \cdot 5) + (3 \cdot 2 \cdot 5) + \left(\frac{300 \cdot 5 \cdot 33.33}{250} \right) = 275$

ΔT_{IB}	Tension Added to the Belt due to the Impact Bed	1230 N	275 lb$_f$

FIGURE 3: Tension added to the belt due to an impact cradle

$$P = (\Delta T_S + \Delta T_{IB}) \cdot V \cdot \mu_{ss} \cdot k$$

Given: *A conveyor belt traveling 1,25 meters per second (250 ft/min) is supported by an impact bed and a seal-support system that add 1230 newtons (275 lb$_f$) and 618 newtons (138 lb$_f$) respectively. The support systems use a UHMW sliding surface.* **Find:** *The power consumption added to the drive due to the sealing and impact support.*

	Variables	Metric Units	Imperial Units
P	Power Consumption Added to Belt Drive	kilowatts	horsepower
ΔT_S	Tension Added to the Belt due to the Sealing Support *(Calculated in Equation Provided)*	618 N	138 lb$_f$
ΔT_{IB}	Tension Added to the Belt due to the Impact Bed *(Calculated in Equation Provided)*	1230 N	275 lb$_f$
V	Belt Speed	1,25 m/s	250 ft/min
μ_{ss}	Friction Coefficient Per CEMA 575-2000	0,5 – UHMW 1,0 – Polyurethane 1,0 – Rubber	0.5 – UHMW 1.0 – Polyurethane 1.0 – Rubber
k	Conversion Factor	1/1000	1/33000

Metric: $P = \frac{(618 + 1230) \cdot 1{,}25 \cdot 0{,}5}{1000} = 1{,}15$

Imperial: $P = \frac{(138 + 275) \cdot 250 \cdot 0.5}{33000} = 1.56$

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P	Power Consumption Added to Belt Drive	1,15 kW	1.56 hp

Power consumption added to drive due to impact cradles and belt support

calculating the theoretical power requirements of proposed changes in belt-support systems.

Added kilowatts (hp) consumption can be calculated by determining the added belt tension, using the standard methods recommended by CEMA. The coefficient of friction of the new (or proposed) support systems, multiplied by the load placed on the belt support from belt weight, material load, and sealing system, equals the tension. There is no need to allow for the removal of idlers, the incline of the conveyor, or other possible factors, as estimates provided by this method will, in most cases, produce results higher than the power consumption experienced in actual use. In applications where there is a lubricant, such as water, consistently present, the actual power requirements may be one-half, or even less, of the amount estimated through these calculations. [Fig. 2, 3, 4]

CONCLUSION

Additional power requirements and costs will seem minor when compared to the power consumed by operating with one 'frozen' idler or several idlers operating with a material accumulation. By implementing the proper belt-support systems, a plant can prevent the more costly problems that arise from the escape of fugitive material. Cleanup of spillage not only increases labour costs but, in lieu of unscheduled downtime, exposes workers to activities around and under a running conveyor, a major cause of injuries and death in the bulk handling industries.

Testing has found that a well-design system incorporates slightly elevated power consumption required to prevent spillage, rather than suffer the much higher power consumption and greater consequences that arise from fugitive material. The costs for installation and operation of proper belt-support systems represent an investment and commitment to ongoing efficiency and workplace safety. •

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