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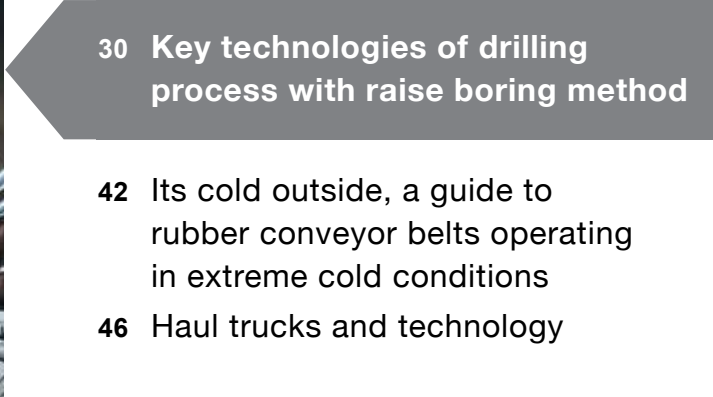
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## Controlling conveyor belt carryback: Cost vs. Payback

### **B**ELT CLEANERS

Virtually every technique and combination imaginable has been tried for cleaning conveyor belts handling bulk solids, including piano wires, high pressure water spays, brushes, vibration and even very small head pulleys to fling carryback from the belt. Most industries gravitate to basic mechanical scraping with a metal or elastomeric blade for flat rubber or PVC belting as the best combination of effectiveness, ease of maintenance and low belt wear to yield the lowest cost of ownership. This article focuses on the effectiveness of mechanical scraping of carryback from a conveyor belt.

### **EFFECTIVENESS VS. EFFICIENCY**

The undulating action of the loaded belt passing over idlers tends to cause fines and moisture to migrate and compact on the surface of the belt. The material that clings to the belt through a combination of adhesion and electrostatic forces – depending upon the characteristics of the bulk material and the moisture content – is called carryback or carryover. Carryback is measured in grams per square meter of dry weight of material that adheres to the dirty portion of the belt (the carrying side).

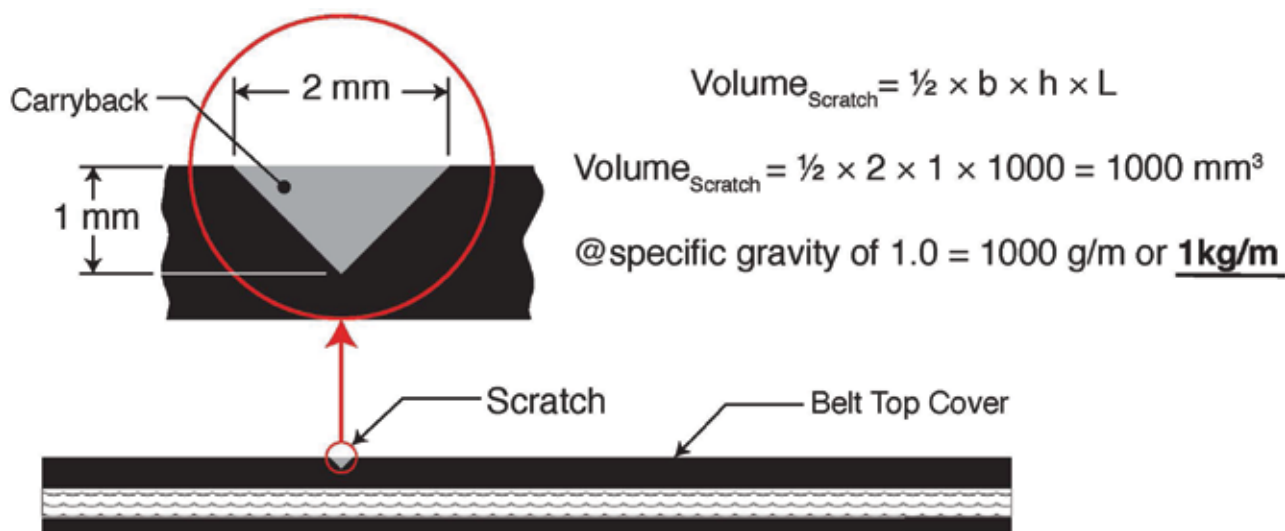
The amount of carryback that clings to the belt can range

from a few grams to a few kilograms per square meter. The level of belt cleaning required is a function of the operational schedule and method of collecting and disposing of the carryback that is cleaned from the belt or dislodged by return idlers and collects outside of the conveyor discharge chute and maintenance. Depending upon the length of the conveyor, the amount of residual carryback that falls along the return or becomes airborne dust after cleaning ranges from 25% for short belts to 75% for longer belts.

It can be shown practically and theoretically that a conveyor belt cannot be cleaned 100%, because the surface of the belt and the blades are not without imperfections or damages. A field study in Australia<sup>1</sup> found the practical lower limit to be between 6 to 60 g/m<sup>2</sup> for tungsten or ceramic tipped belt cleaners, depending on belt surface, blade micro roughness and wear.

Carryback particles range from a few microns to a few millimeters in size. A micron is one millionth of a meter (0.000394 in). To put that in perspective, a human hair ranges from 50 to 100 microns thick. Finer particles can get trapped in the belt's imperfections or become attached to the belt top cover by powerful capillary, electrostatic and nuclear forces, making them very difficult to dislodge from



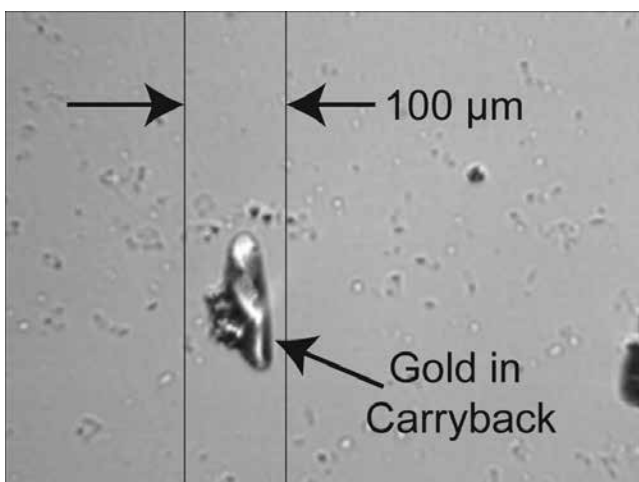


**Figure 1:** Small scratches and worn belt surfaces can hold significant amounts of carryback.

the belt and then flow away from the surface of the blade. If the scraped material cannot flow off the blade fast enough, it accumulates, hardens and builds up, creating a large shelf that may cause the blade to hydroplane and stop cleaning.

Belt cleaning is a process, and the effectiveness varies day to day with conditions, the number and type of cleaners applied and the maintenance they receive. Keeping the material in the process is always better than letting it accumulate on components and build up under the conveyor. Whether the cargo is valuable or not, it makes sense to keep as much of it in the process as possible. As much as 3% of the cargo can be lost due to spillage, dust and carryback. World class operators average less than 0.1% fugitive material loss, reducing direct operating costs. The exposure to hazards and injuries is reduced when less cleanup is required, saving significant, but seldom considered, indirect costs.

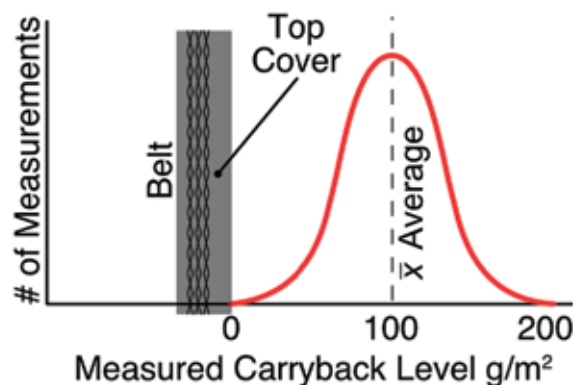
Carryback often contains concentrated material due to the undulating action of the belt as the cargo passes over idlers, migrating fines to the belt surface. When handling high value bulk materials it is common for the carryback to have a higher concentration of desirable mineral than the main cargo. **Figure 2** is a microscopic photo of gold ore carryback containing a miniature gold nugget. The 100 micron lines are approximately the width of a human hair. An assay showed there was 40% higher concentration of ore in the



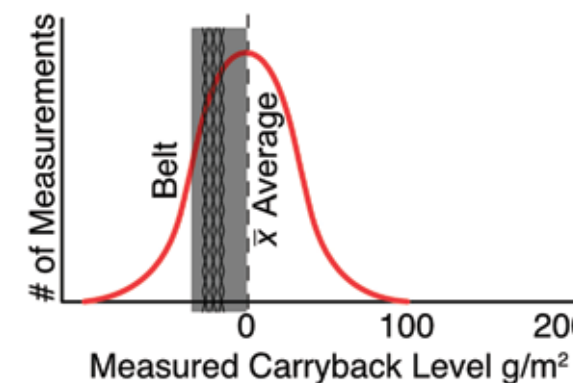
**Figure 2:** Controlling carryback doesn't cost. It pays.

carryback than the "as mined" ore. It doesn't make sense to put material on the conveyor and have to deal with it again as accumulations of carryback. The cost of lost product, cleaning and (if possible) returning it to the process is significant.

Since belt cleaning is a dynamic activity in which the results change constantly, for the average ( $\bar{x}$ ) carryback to be zero (100% clean) a small fraction of the top cover has to be removed 50% of the time. The key to consistent cleaning effectiveness is to control the process through proper selection, installation, inspection and maintenance of the belt cleaning system and establish a safe cleanup routine and schedule.



**Figure 3:** Belt cleaning is a process with varying results.



**Figure 4:** Averaging 0% carryback requires removing some top cover.

# CONVEYOR BELT CLEANING A MARTIN ENGINEERING PERSPECTIVE

The use of multiple mechanical scrapers on a belt has been accepted for quite some time as an effective approach to belt cleaning. In coal mining and handling, the amount of carryback that can be tolerated is very small, due to fire and explosion hazards when compared to that which is acceptable in rock quarries, for example. The real question is: How much carryback per hour can the system tolerate and still function safely until scheduled cleaned up? In most operations, multiple cleaners are required to reduce the carryback to a safe, acceptable level while limiting manual cleanup to weekly or even monthly tasks.

When discussing the *efficiency* of a belt cleaner, it's meaningless to talk about efficiency without stating the initial level of carryback. When considering the beginning and ending levels of carryback as a measure of improvement, *effectiveness* is a better term. Some guidelines do exist. The U.S. Bureau of Mines states that an average of 100 g/m<sup>2</sup> is a reasonable level of performance for belt cleaning. At this level the belt may have visible streaks of discoloration or wet bands but not create excessive buildup on components or piles on the ground. A typical manual shoveling rate is 1 ton per hour or less, depending upon access and disposal methods. At 100 g/m<sup>2</sup> a 1200 mm (48-inch) belt traveling 2 m/s and operating 24/7 would create a cleanup workload of about 7 tons per day. If the conveyor is elevated from the surface at the tail greater than what most standards state as the minimum clearance of 300 mm (12 inches), cleanup schedules could be manageable.

CEMA standard 576 is a rating system based on belt and bulk material conditions and level of desired cleaning for specifying belt cleaner performance. The standard uses belt attributes and material characteristics to develop its ratings, using CEMA Standard 550 to assign values for the material categories. The factors include the conveyor speed, belt width and splices, as well as the material's abrasiveness and moisture content. Each is scored individually and then totaled to arrive at the class rating for the application. The final score is divided into five application ("Class") levels that should be considered when cleaners are being selected. Appropriate cleaners should have a rating that meets or exceeds the calculated application class score.

It is the ending carryback level that determines the cleanup schedule. In reality, a typical belt cleaner loses effectiveness over time due to lack of inspection, cleaning and maintenance. On systems with average or poor maintenance, effectiveness values are more in the range

of 40-60%, thus the need for multiple cleaners. Regular cleaning of the blades or the use of water sprays can improve these values by ~15%<sup>2</sup>.

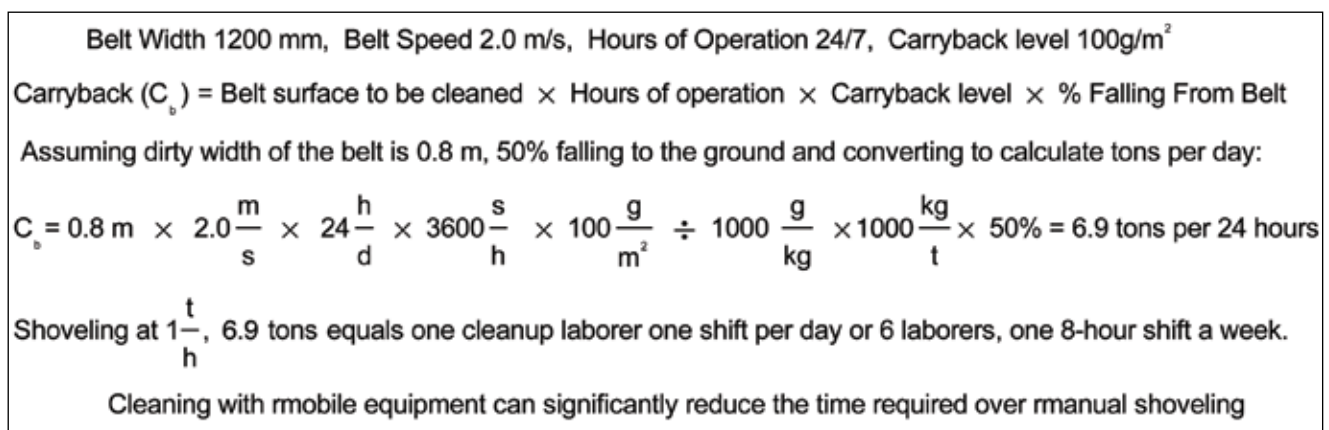
For example, to state a cleaner is 60% efficient implies a fixed performance regardless of influencing conditions like tonnage, moisture, clay content, maintenance or the weather – just to name a few of the variables that affect belt cleaning. A 60% effective cleaning of a belt containing 1 kg/m<sup>2</sup> (leaving 400 g/m<sup>2</sup> on the belt) of carryback is not the same performance as 60% cleaning of a belt with 100 g/m<sup>2</sup> (leaving 40 g/m<sup>2</sup> on the belt) when it comes to the amount that must eventually be cleaned up around the conveyor. The lower limit for consistently cleaning a bulk material handling belt is in the range of 5 to 10 g/m<sup>2</sup> and normally can only be obtained using multiple cleaners and water sprays.

## CLEANING LOCATION

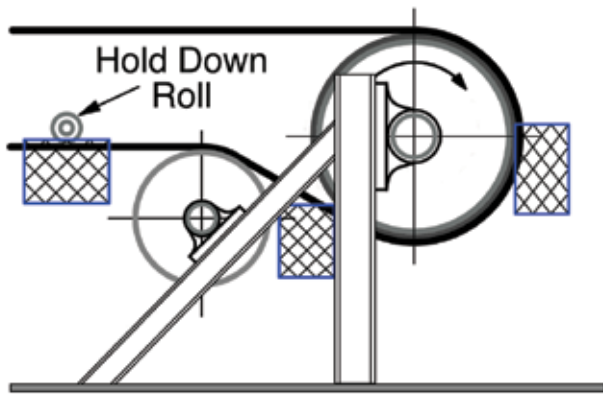
CEMA<sup>3</sup> has established nomenclature for the location of belt cleaners. Unfortunately, designers often focus on the lowest installed cost of the structure around the head and snub pulleys, without allowing enough space for optimum cleaner installation in an effort to reduce prices. Incorrect mounting location from the face of the belt is another common cause of poor cleaner performance, which introduces significant long-term costs that can be mitigated with cleaner-friendly structural arrangements. Access to cleaners restricted by structure or drive components reduces the ability to inspect, clean and service belt cleaners and therefore also contributes to reduced cleaning effectiveness.

**Figure 6** shows the clear areas needed on the chute for installation of belt cleaners in the optimum positions. The installations should be at an ergonomic height above the work platform to encourage proper inspection and service. Consideration in the design stage for locating cleaners in the optimum locations will lead to more effective inspections, maintenance and belt cleaner performance. A large enough discharge pulley (> 600 mm Ø [24 in]) can often accommodate two pre-cleaners, which is desirable since the cleaned carryback will flow with the main stream of cargo and reduce or eliminate the issue of buildup on the dribble chute.

Belt cleaners can be placed anywhere along the return run of the belt, as long as the belt is supported in some fashion. Since it's desirable for the carryback cleaned from the belt to be returned to the main material flow, most belt cleaners are installed inside the discharge chute. Cleaning on the head pulley, labeled the 'primary



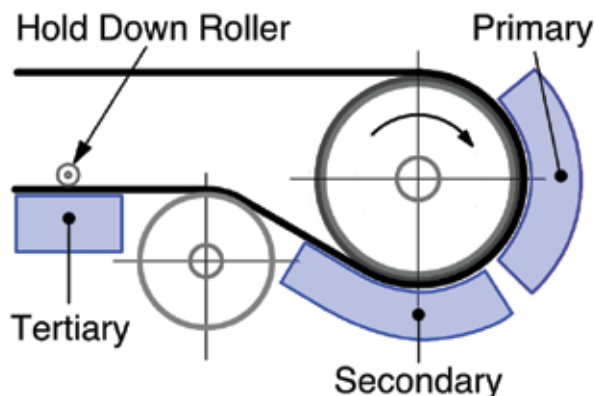
**Figure 5:** Typical carryback cleanup labor requirement calculation.



**Figure 6:** Arrange structure to optimise cleaner locations and for service friendly access.

cleaning position,' is preferred. Cleaning the dirty side of the belt before it reaches a snub, bend pulley or return idlers is considered less desirable, requiring a dribble chute for cleaners in the secondary position. The secondary position is complicated by another fact: the nature of carryback is such that it can adhere to vertical surfaces and not flow down a sloped dribble chute. A tertiary position is sometimes required for critical applications such as conveying over wetlands. In such cases, the tertiary cleaners are often enclosed in a spray box and the effluent directed to a settling basin. Most cleaners, when located more than a few cm (inches) from where the belt leaves the discharge pulley, require a backup or hold down roll to keep the belt stable for blade to belt contact and control belt flap (vibration).

Carryback fines are often so sticky that they will adhere upside down on horizontal surfaces and cling to vertical surfaces. This creates a need to regularly clean the dribble chute. There are several approaches to dribble chutes. If the chute walls can be vertical, there will be less buildup. However, a vertical dribble chute creates other design issues, primarily the added length of the receiving chute at the loading point. Low-friction liners or live bottom chutes are effective at reducing the rate and volume of buildup on chute walls. Cleaning chute buildup from below often involves confined space entry and the hazard of falling masses of agglomerated material.

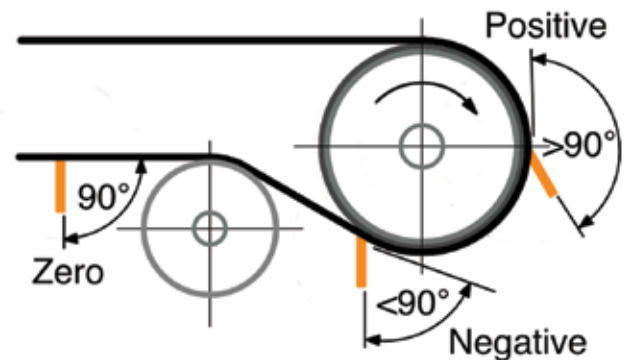


**Figure 7:** CEMA nomenclature for preferred belt cleaning positions.



**Figure 8:** Vibrator with bracket and low friction plastic chute liner.

## BLADE ANGLE OF ATTACK



**Figure 9:** Belt cleaner blade attack angles.

Mechanical blade style cleaners are classified by the angle the blade makes with the belt, called the *angle of attack*. There are three basic angles of attack: positive, negative and zero, named for machine tool rake angles. The positive angle of attack delivers a *peeling* action and the negative angle a *scraping* effect. In the past, a zero angle of attack was common for counterweighted single blade slab-style cleaner designs and is still used for squeegeeing water from the belt. Typical positive rake angles for belt cleaners are 135 degrees and for a negative rake, 85 degrees.

The force required to hold the blade in the cleaning position is different for various blade materials and angles of attack, determined by the reaction forces that the belt cleaner support frame and mounting system must accommodate. It is general practice to make the mounting substantial, but able to provide relief to protect the belt in case of a major impact or upset condition, such as a plugged chute.

From **Figure 12** it can be deduced that for metal blades, as the residual carryback layer "r" becomes smaller, the force to hold the blade in position becomes greater, eventually reaching infinity with "r" equaling zero. For an elastomeric blade at zero rake, the carryback remaining on the belt can be estimated as:  $r \approx 0.33 \times \mu \times V \times L \times 2B$  where L is the blade length and B is the elastomer's modulus<sup>4</sup>. Similarly, for "r" to equal zero with an elastomeric blade, one of the terms or variables must be zero, which is not possible. Thus, it is theoretically impossible to clean the belt 100% all the time.



# CONVEYOR BELT CLEANING A MARTIN ENGINEERING PERSPECTIVE

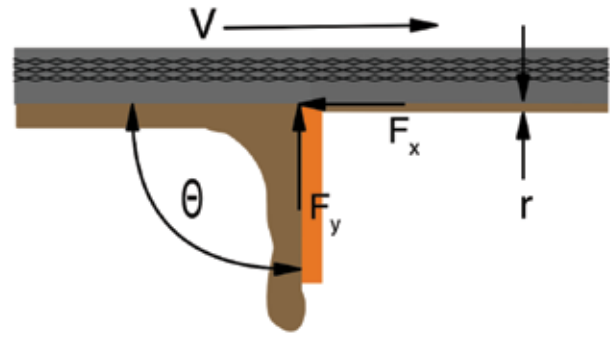


Figure 10: A zero rake biased metal tipped pre-cleaner.



Figure 11: A negative rake metal tipped secondary cleaner.

The positive rake blade tends to shed carryback more readily, reducing the potential for buildup of carryback on the blade, which reduces cleaning effectiveness. The positive rake angle requires the least amount of force to hold the blade in position and is the most effective cleaning angle. The position is also forgiving when the belt reverses or momentarily rolls backward. In the positive rake orientation, the leading edge of a hard metal blade is honed razor sharp by abrasive carryback and therefore is usually applied only on belts in good condition with vulcanised splices and where proactive maintenance is practiced. The use of elastomeric blades in the positive rake position reduces the chances of a razor-sharp edge



$\mu$  = Carryback Viscosity     $r$  = Carryback Thickness

$$F_x = \frac{2 \times \mu \times V}{r} \times \left( \frac{\theta - \sin^2(\theta) \times \cos(\theta)}{\theta^2 - \sin^2(\theta)} \right)$$

$$F_y = \frac{2 \times \mu \times V}{r} \times \left( \frac{\sin^2(\theta)}{\theta^2 - \sin^2(\theta)} \right)$$

Figure 12: Required force to hold metal blades in position<sup>5</sup>.

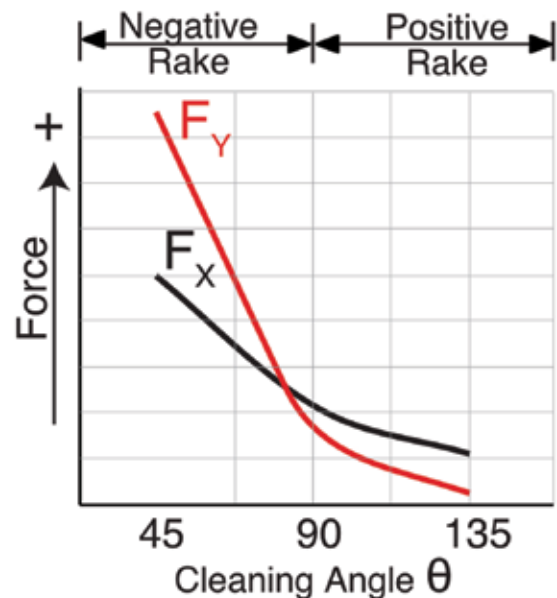
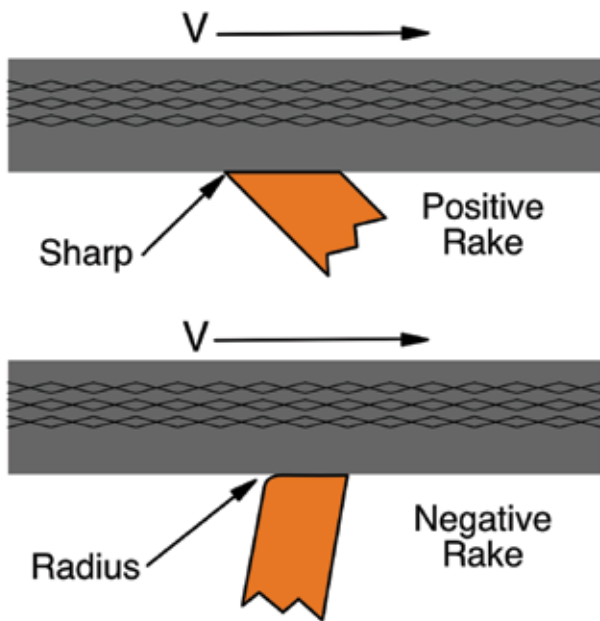


Figure 13: Relative forces required to hold metal Blade at positive and negative rake angles.

attacking the belt, while still cleaning effectively. Negative rake oriented hard metal blades form a small radius on the leading edge and are often used on damaged belts or when mechanical splices are present. The negative rake blades, having formed a leading radius, allow obstructions to pass more easily than the positive rake but are less effective in cleaning.

Many negative rake cleaners are designed to be installed on the belt at a zero-rake angle and when the belt moves, the mounting apparatus allows the support to respond so the blade is slightly tilted in the direction of travel, forming a negative rake angle of attack. This angle is less forgiving to reversing operation or belt rollback than the positive or zero rake. Negative rake cleaner support systems are often designed to allow the blade to accommodate momentary reversals.



**Figure 14:** Leading edges wear differently depending upon rake angle.

Some zero-rake belt cleaner blades are positioned at a bias rather than perpendicular to the belt travel direction. Zero rake at a bias delivers effective cleaning and safe relief when an obstruction such as a mechanical splice, passes.

### BLADE PRESSURE

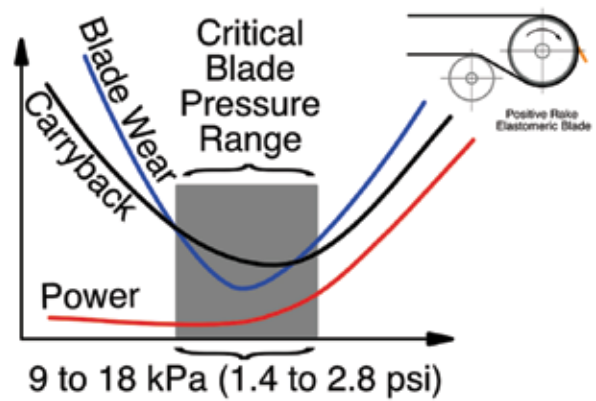
There have been several studies that indicate optimum cleaning pressures for secondary and primary belt cleaners<sup>6,7</sup>. Without enough cleaning pressure, the blade cannot stay in contact with the belt, resulting in poor carryback removal effectiveness and increased blade and belt wear. With too much cleaning pressure, the cleaning performance declines due to deflection of elastomeric blade or metal blade indentation into the rubber belt. Power consumption also increases dramatically with too much cleaning pressure.

**Figures 15 and 16** show that there is an optimum range of cleaning pressures for different cleaner designs and blade materials. Increasing the cleaning pressure does not necessarily increase cleaning effectiveness. Keeping a belt cleaner properly tensioned is critical for maximum effectiveness and lowest cost of ownership. The optimum blade material and cleaning pressure recommendation is usually based on the supplier's experience. Because there are so many variables in effective belt cleaning, sophisticated operators will go through an optimisation routine to determine the best combination of blade angles, blade materials and pressures. Sometimes these operators will change blade materials and pressures based on the seasons or the bulk materials being handled.

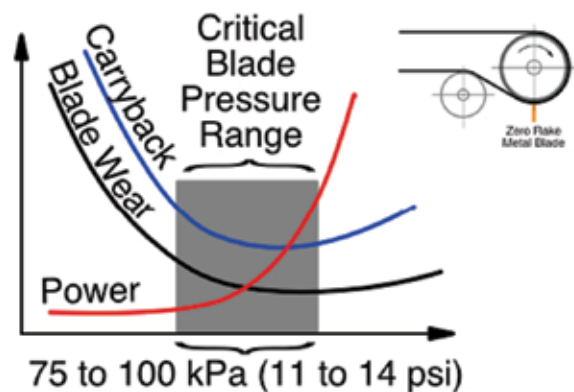
### BELT WEAR AND DAMAGE

Almost all reputable developers and manufacturers of belt cleaners offer many product variations to meet specific needs and conditions. These companies invest in R&D and training of their service technicians to provide the optimum performance and often provide enhanced warranties.

While belt cleaners do cause some wear of the belt, it has been shown that the wear from belts sliding over frozen idlers or piles of carryback is significantly greater<sup>8</sup>. A well-engineered and manufacturer-installed belt cleaner will



**Figure 15:** Elastomeric primary blade pressure at a positive rake.



**Figure 16:** Metal secondary blade pressure at zero rake angle.

contribute 2-3% to the wear of the top cover over the life of the belt, so even a triple cleaning system will account for less than 10% of the belt wear. In contrast, wear from loading is on the order of 40% of the total belt wear. Most belts are replaced due to damage or neglect rather than normal wear.

If belt cleaners are not inspected, cleaned and maintained regularly, they have the potential to cause belt damage from loose or vibrating blades or bent support frames catching and holding large lumps against the belt. Cleaners with a positive rake are more prone to natural frequency vibration, which can be initiated by something as simple as a raised splice or hole in the belt. Negative rake cleaners are more tolerant of belt damages. Most problems can be detected by simple visual daily inspections to minimise damage.

### FINAL THOUGHTS

Many belt cleaner systems are installed and forgotten. A survey of technicians indicates that about 25% of all belts have cleaners installed, and of that percentage only about 25% are properly maintained. The vast majority of these cleaners are basic mechanical scrapers. While the initial cleaning results may be significantly better than the previous performance, lack of inspection and maintenance results in accepting a gradually lower level of effectiveness, a higher level of operating cost and an increased exposure to the hazards associated with cleaning up carryback.

Effective belt cleaning starts in the design stage, with providing adequate space for belt cleaners and positioning work platforms for ergonomic inspection and maintenance access. Belt- and service-friendly designs improve production and prolong the life of equipment. In general, the safest belt





**Figure 17:** Positive rake / loose blade chatter marks.

cleaning is done with the blade in the zero or negative rake position, while the most effective cleaning is done with the blade in the positive rake position. If the cleaners are located in the optimum positions and easy to access, it is more likely that regular inspection, cleaning and maintenance will be performed, resulting in optimum effectiveness.

Proper selection, installation, inspection and maintenance of conveyor belt cleaners can provide an immediate return on investment simply from reduced cleanup labor. Effective belt cleaning produces often-overlooked savings from reducing wear on belts and components, minimizing worker exposure to the hazards of cleaning around a conveyor and maintaining them sporadically in hard-to-access locations.

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