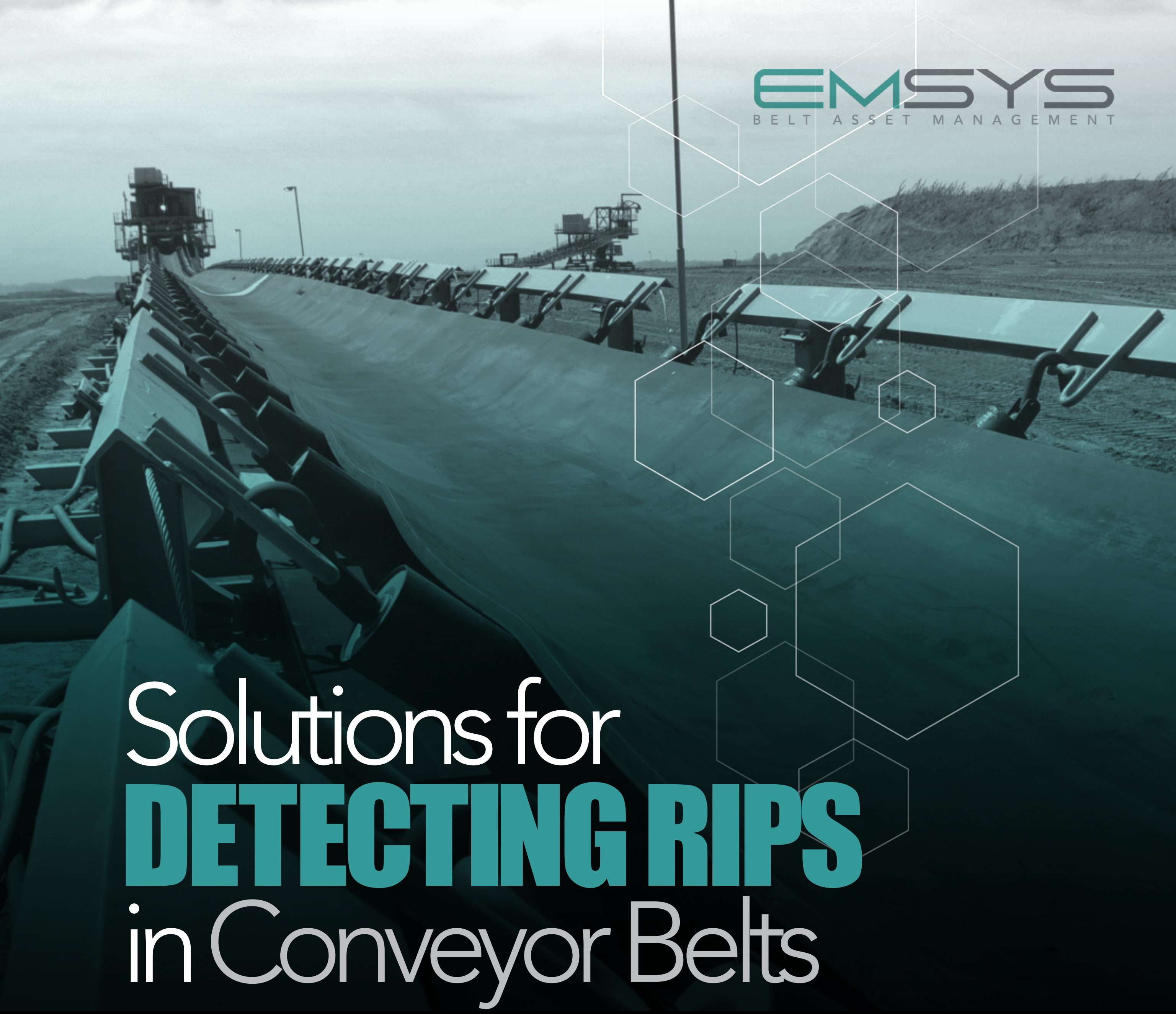

Solutions for DETECTING RIPS in Conveyor Belts

ANDREW I. HUSTRULID, PHD, PE

Conveyor belts rip longitudinally primarily by being impinged by foreign objects such as drill steel, rock bolts, steel liner plates or rock slabs that penetrate through the belt and become lodged in the impact bed structure or surrounding steel. The majority of time the rip occurs at the tail or loading point of the conveyor but occasionally does occur elsewhere along the conveyor.

Steel cord belts are particularly susceptible to belt rips as they have no, or limited, rip resistance strength. Once a foreign object penetrates the belt there is nothing to force the object free, so it is not uncommon to see the entire belt length rip into two pieces. Belts carrying primary crushed ore are occasionally fitted with an additional fabric or metal breaker layer to provide additional impact resistance. This can provide some additional protection against damaging the steel cords but only offers limited protection against rips. »

The consequences from a rip in a steel cord belt are significant. Rips are generally long and make the conveyor essentially inoperable. These belts are often the lifeline of the mine carrying the ore from the primary crusher a long distance to the processing plant or coal up the steep slope out of an underground mine. Steel cord belts are only made to order and typically have a multi month lead time to be manufactured. The costs of the belt and the replacement service can also be substantial. Vulcanized repairs and/or installing mechanical clips offer temporary, but marginal, results in returning to operation. Frantic calls looking for used steel cord belt around the world are not uncommon following the rip of a steel cord belt.

For these reasons it is not uncommon for mining companies or their insurance companies to require that rip detection systems are installed and in operation on critical steel cord conveyors.

Fabric conveyor belts are less impacted by rips. Due to their multiply woven nature foreign objects are less likely to penetrate the entire carcass. When an object does penetrate the carcass the strength of the carcass may dislodge the object from the belt and/or the rip will migrate out the side of the belt limiting damage to a limited portion of the entire length. Straight warp fabric designs have historically performed well in high impact and potential rip applications. Fabric belts are also commonly held as spares, stalked at distributors, or available with a lead time of a few weeks from the manufacturer limiting the necessity for rip detection in fabric belts.

Over the last 5 decades a few different types of rip detection systems have been developed.

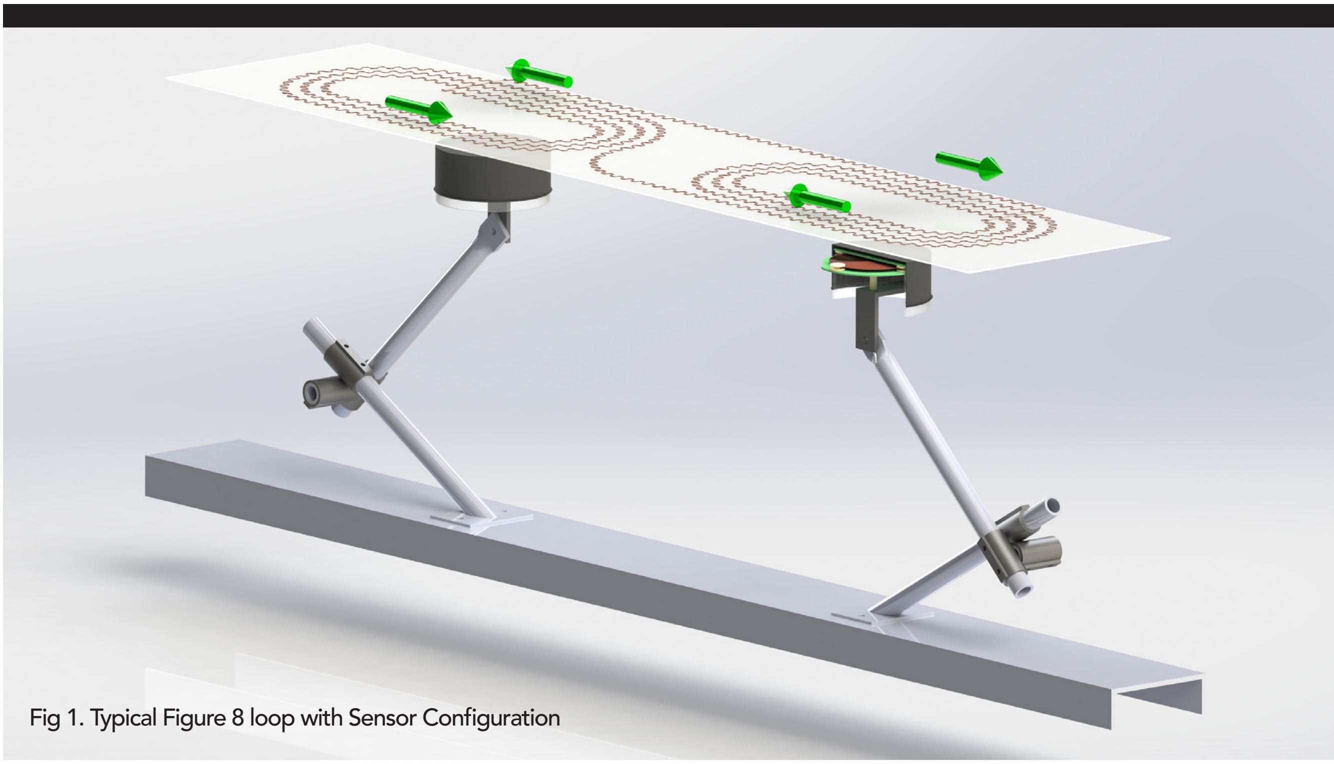

Fig 1. Typical Figure 8 loop with Sensor Configuration

A LOOP BASED SYSTEM

The most common systems in use today are 2 different loop-based systems where an inductive loop is placed in the conveyor during manufacturing and later read with a transmitter and receiver in the field. If a loop is expected, but not found, the controller concludes that the loop has been cut and the conveyor is stopped. The transmitter and receiver to detect the loop are generally placed a short distance following the load point.

The general principal is that a transmitting coil generates an electromagnetic field (EMF) at a relatively low frequency of approximately 56.5 kHz. If the coil in the belt is intact a current is induced which then generates a second EMF that is detected by a receiving coil mounted on the opposite side of the conveyor. If the coil in the belt is not intact the receiving coil should not receive a signal.

However, due to their relatively close proximity of only the belt width, one challenge is when the transmitter and receiver "couple" to each other when no loop is present. This can be caused by the positioning of the sensor heads, high gain and/or sensitivity settings, a splice in the belt or other metallic objects on the belt.

Two methods have been employed to avoid the coupling issue:

- When using the "Figure 8" loops the signal detected by the receiving antenna is reversed or inverted when the loop is present. The system knows that a loop is there and not some other object when the signal reverses.
- The systems with the rectangular loops take a completely different approach. The transmitter and receiving heads have a polarization in their electromagnetic fields. When they are positioned approximately perpendicular to each other their fields do not interact. Here the word approximate is used because there is some fringing of the fields and they are not perfectly polarized. The long transmitting coil creates a current in »

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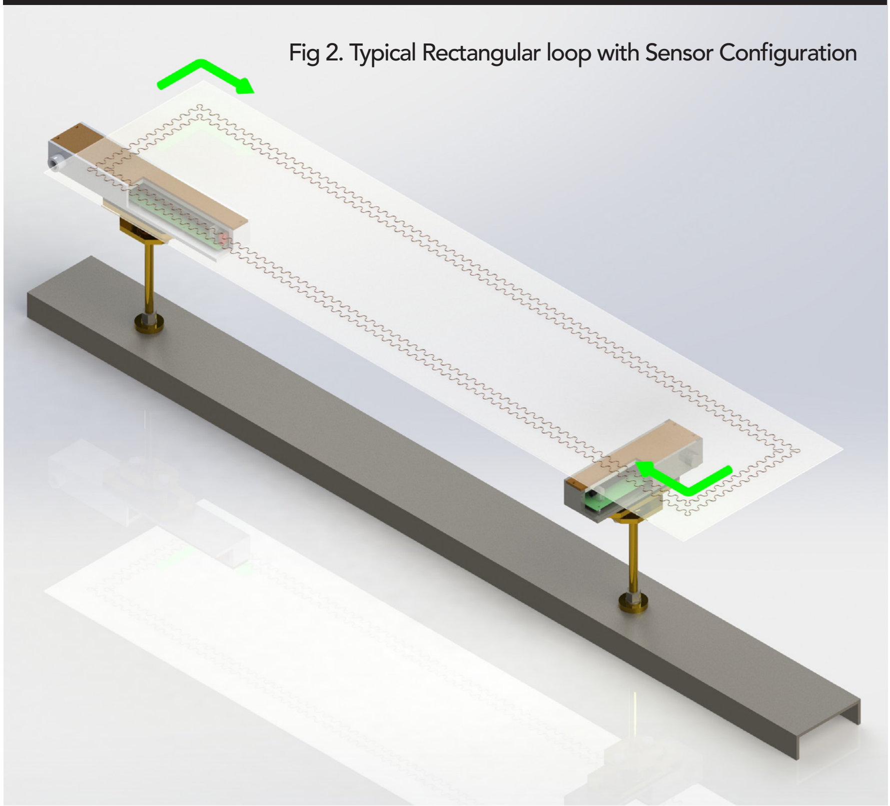

Fig 2. Typical Rectangular loop with Sensor Configuration

the end of the loop and the receiving coil picks up the current from the wires that cross the belt width.

These systems have worked over the years but many mines and service technicians report that they can be difficult to maintain and can have false nuisance trips that are costly to follow up on, lead to unplanned down time and may eventually lead to the system being turned off completely or not believed when an actual rip does occur. Better understanding of the systems, improved software, user interfaces and remote monitoring have improved the usability of these systems.

Typical difficulties that have been experienced over the years are:
1) physical damage to the systems,
2) poor or intermittent reading of the loops and
3) the system not knowing where it is in the revolution of the belt.

Operating in a mining environment it is not uncommon for the systems to be physically damaged. Types of damage experienced are severe corrosion due to the corrosive mine environment, sensors position being changed or completely dislodged due to impact from material falling off the belt, and sensors or control boxes being flooded in wet mining environments. To overcome these challenges control boxes are available in stainless steel or hard plastic cases, sensors are encased in epoxy or secondary hard plastic cases, and it is recommended that the customer carry spares of all components mounted on or near the conveyor.

The principal of these loop systems is an inductive loop is installed in the conveyor. Reliable reading the loops while also seeing a false loop when one isn't present is a challenge.

The loop can be installed in either the top or bottom cover. Installing the loop in the bottom cover provides additional protection from impacting material and will place the loop closer to the transmitter and receiver without the steel cords of the belt between the two. However, often a thicker pulley cover is required to accommodate the thicknesses of the loop. Typical minimum cover thickness to accommodate the loop is 6mm.

The wire used in the loops is carefully selected to resist fatigue and corrosion. Typical constructions are a copper core enclosed in stainless steel shielding. The solder joint of the two ends of the wire is a potential failure point so cable splices are typically done with individual strand ends staggered at up to 7 unique locations around the loop. Additional attention needs to be paid to the rubber compounds used to encapsulate the antennae to ensure they do not react with the core metal or the shielding.

The figure 8 sensors are show in Figure 1. The transmitting coil is supplied with 15 volts. When a loop is not present the transmitter can couple with the receiver. Antenna on the surface of the PCB act to align the rf waves.

The current generated by the transmitter can be seen moving in the opposite direction as it passes over the receiver in the Figure 8 Loop

Systems using the rectangular loops use transmitters and receivers with polarized linear radio frequency fields. The system operates at 12 volts and a frequency of 56.5 kHz and the long transmitter generates a current in the wire at the end of the loops nearest the belt edge. The receiver is placed perpendicular over the wires crossing the belt picks up the signal. The signal in the receiver changes direction as the sensor passes under the middle of the loop. The rectangular loop configuration is shown in Figure 2.

One byproduct of the close integration between the sensor types and the loop design is that different sensors don't necessarily work well with alternate loop types. The linear sensor heads can usually read the figure 8 loops, but the cylindrical sensor heads cannot read the rectangular loops. This can lead to replacement belt sales tied into a particular belt manufacture. Several different belt manufactures utilize the rectangular loops. »

By adding a speed sensor to the system, the control unit can keep track of the position of the belt as it moves around the system.

OPERATING MODES

In the simplest operating mode, the controller keeps track of the maximum time expected between each loop. The PLC informs the system that the belt is running and if a loop is not detected within a set number of seconds the system flags that the belt has been ripped.

By adding a speed sensor to the system, the control unit can keep track of the position of the belt as it moves around the system. Instead of the basic time between loops the system can now keep track of the distance between loops. Knowing the position of the belt as it rotates around the conveyor system is critical. The speed sensor is typically measured on a non-driven pulley in case there is belt slippage. Modern systems use 2 encoders detecting targets on the pulley shaft or the pulley rim. Duel encoders are required to pick up not only belt speed but the direction of rotation. As the belt start or stops a pulley may temporarily run backwards. With only one proximity probe this may look like additional space in the belt which causes problems. Additional recommendations are to use industry standard speed measurement devices, duel output sensors to reduce the number of sensors required on the pulley, for systems mounted near the head of the conveyor system the speed detection should be mounted on the same side of the take-up as the sensor heads, and the finally the spacing of the speed targets on the pulley should be equally spaced.

More advanced operating modes learn the pattern of loops in the conveyor and then based on either a short or long loop spacing can identify a starting position in the belt. While the system is either learning the loops spacing or looking for the start of the pattern it will operate in the maximum loop spacing mode. In practice this model can be problematic as weak loops may or may not be picked up during training, short (or long) loops spacings may be similar in the belt, and the system must be retrained when there are any changes to the conveyor such as adding or changing a splice.

Starting in 2005 manufactures started installing RFID chips adjacent to the rip panels. These chips picked up by a separate sensor each had a unique id associated with them and enables the system to immediately know where it is in the belt revolution once the first RFID chip passes the sensor. This improved the availability of the rip detection systems significantly. The RFID chips can either be installed at the time of manufacture or retrofit into existing systems in the field. It is also common to install at a minimum 1 RFID chip in the conveyor so that at a minimum the system can find 1 unique start point.

RFID chips are being used in conveyor belts for other purposes. Examples include marking the splice locations and details and marking distances from just before to after the splice in an effort to monitor splice stretch which may indicate impending failure. RFID readers may also read the chips as the pass on the belt going in the opposite direction. For example, an RFID sensor monitoring the carry run of the belt may also pick up the RFID chips as the pass on the return run on the opposite side of the conveyor. It's critical to not only return that an RFID chip was present but also the ID number of the chip.

PROBLEMS WITH BELT MISTRACKING

The performance of the system is dependent on the sensors in the belt properly positioned over the transmitter and receiving heads. If the belt mistracks this causes the relative position of the loops to the sensor heads to shift and the read loop strength may decrease.

With the rectangular loops the allowable mistracking is limited by the length of the transmitter which passes over the end of the loop. In 2002 the transmitter length was increased from 250mm to 400mm to allow for more mistracking. This should allow the belt to track +/- 200 mm.

The figure 8 loops initially had 2 smaller circular loops that were designed to pass over the transmitter and receiver. This permitted minimal mistracking. Over time the pattern has changed to two elongated loops. The length of these loops is dependent on the belt width. For a 1524mm wide belt the permitted mistracking is approximately +/- 160 mm.

The size and placement of the loops in the belt is also critical. If the loops are not located consistently across the belt width, or a smaller loop is inserted, sporadic problems with the reading of the loops can occur leading to false trips.

Belt lift off during starting or running at the location where the sensor heads may also lead to false trips. When the belt lifts off the loops are farther away from the sensor heads, decreasing the signal strength, and potentially resulting in a missed loop.

For optimum reliability with the loop system the belt should track consistently over the transmitter and receiving heads, all of the belt loops should be the same size and consistently located across the belt width and the belt should maintain positive contact with the adjacent idlers at all times. »

THE NEXT GENERATION OF RIP DETECTION

Due to Recent Technology Advancements

RFID technology has significantly advanced since 2005. The chips are now amazingly small, can be read from further distances and can also include sensing and measurements. There is significant commercialization of RFID chips beyond conveyor belts which has led to industry wide standardization and significant development.

Smartwires are constructed of a Kevlar® braided core for impact resistance and strength. They are made of a silver coated copper wire wound around the Kevlar® core which is then stitched in a z pattern to breaker fabric for resistance to breakage. The solder joints and RFIDs are encased in epoxy to prevent breakage and ensure the longevity of the signal. Each Smartwire

Table 1 Industry Standard RFID Frequencies

	STRENGTH	RANGE	FREQUENCY
LOW FREQUENCY	Ability to Penetrate metal surfaces	8 inches to 6 feet	125 - 134 kHz
HIGH FREQUENCY	Medium to High water content	Inches to a couple of feet	13.56 MHz
ULTRA HIGH FREQUENCY	Good for transmitting data	Up to 50 feet	433 and 860 - 960 MHz

There are three common frequency ranges used with RFID that are summarized in Table 1.

EMSYS is the first company to fully incorporate these technologies into belt rip detection.

Instead of a large antenna inserted into the belt, the EMSYS system has two RF tags mounted in the belt, one on each side, and connected by two wires. These are referred to as Smartwires. The two chips operate at industry standard RFID frequencies of HF and UHF. One chip draws power from the external transmitter and powers the other chip that is picked up by the receiver. If the connection between the two chips is lost, due to a belt rip, then the receiving RFID tag reports that the power antennae is cut, and the belt is shut down. To keep the transmitter and receiver from interfering with each other they are operated at different industry standard frequencies.

has a power tag and an antenna RFID and the tags can be programed with information such as: Unique id codes to map to the position in the belt, the date of installation, maintenance dates, etc. Smartwires are warrantied for 1 year from failure and will not impact the performance of the belt or lead to belt failures.

Smartwires are placed within the belt, during manufacture or as a 35-minute retrofit for existing conveyor belts, at regular intervals for monitoring the length of the belt. Smartwires are also manufactured in house at Almex facilities and have short lead times the orders. They do not require special shipping or handling such as refrigeration, because they don't contain any uncured rubber and are flexible by design. In fact, they can be delivered by courier due to the flexibility and lightweight construction.

Smart Wire

Fig. 3 Smart Wire and Sensor Heads

THE PATH TO THE FUTURE

There is a large installed base of rip detection systems in the market. It is unreasonable to expect an end user to replace, at one time, all of their existing loops with Smartwires. However, the end user will still want to take advantage of this new technology.

The EMSYS transmitter and receiving heads are designed to read both the existing figure 8 »

The EMSYS transmitter and receiving heads are designed to read both the existing figure 8 and rectangular loops in the field as well as the new Smartwires.

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Installing an EMSYS system as a secondary system or replacement system on an existing conveyor with rip detection will expose the additional software advances in the EMSYS system and as loops are gradually replaced with smart wires the overall system reliability will improve.

MAINTENANCE OF FAILED LOOPS IN THE FIELD

Fatigue & Manuafacturing Defects are Common Factors for Belt Failure

The antenna loops do fail. They may fail due to material impact, fatigue, cuts into the conveyor covers or a manufacturing defect. As the loops begin to fail, they may just weaken in their signal strength or show up sporadically – sometimes active and other times not active. These failing loops are a significant contributor to false and nuisance trips with rip detections systems. To reduce the issues with these failing loops it is typically possible to program the controller to ignore specific loops or not look for a loop during specific segments of the belt. Failed loops do not need to be physically removed from the belt, but they should be physically cut and approximately a 25 mm section of the wire removed from the belt, so they are completely inactive. Where the loop is cut can be repaired with a quick curing urethane type compound.

When a loop fails, that segment of the belt now has a longer unprotected length. If the original loop spacing was 30 meters, that segment of belt, is now unprotected for 60 meters. To return to the original protection level a new loop needs to be installed. For antenna style loops this requires that the belt is stopped at the correct location, the conveyor is appropriately locked and tagged out, a section of the top or bottom cover is removed, the new loop and covers are installed and the rubber vulcanized with a press approximately 800 mm wide. Once cooled the belt can be removed from service. This process, after the belt is tagged out, should typically take an experience crew about 4 hours. The antennae are typically supplied from the belt manufacture in a rubberized panel compatible with the belt rubber.

The Smartwires with RFID Tags are much smaller at only 100mm wide. With a specialized grooving device and small, lightweight press, they can be quickly replaced in under an hour with two people. This technique is shown in Figure 4 »

BELT INSTALLATION

The coordination of the manufacture of a large steel cord belt with the steps for the planned installation onsite is often overlooked. The OEM or customer orders a new steel cord belt with specified loops spacing of, for example 30 meters. The belt manufacturer makes the belt with a loop spacing of 30 meters, but due to the way steel cord belts are manufactured the roll lengths have minimal variations in length. If all the rolls are installed exactly in the direction and order they were manufactured in, then the loop spacing on the installed belt will be correct. However, this is often overlooked, and the belts installed in a random order which results in significant variations in the loops spacings around the splices. Some being shorter than expected and others longer. Even less ideal is when a few, possible half, of the belt rolls get installed in the opposite direction than the remainder. This can lead to tracking problems which is detrimental to rip detection, and in the case of RFID tags where there is a specific edge of the belt that needs to be over the reader a big problem.

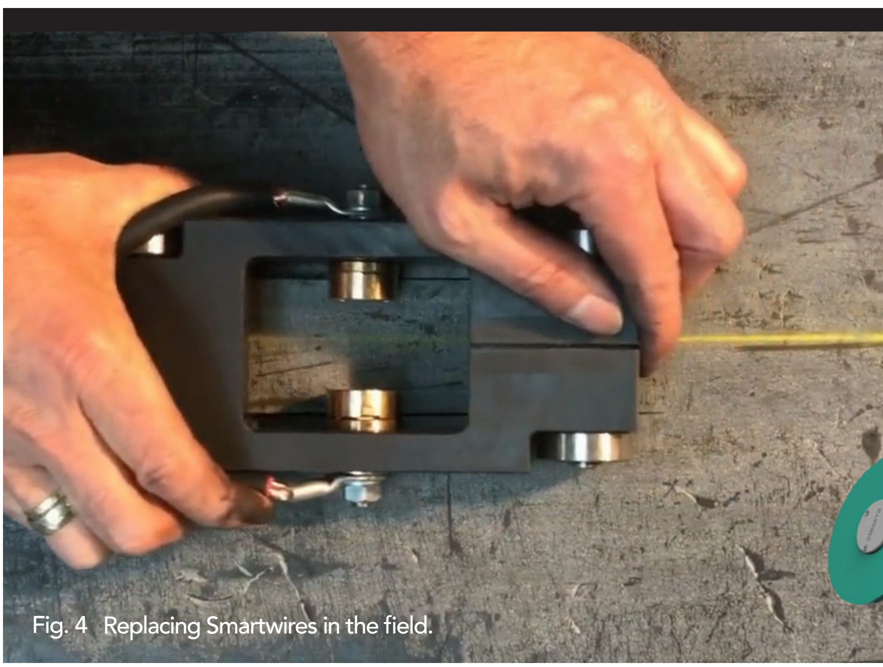
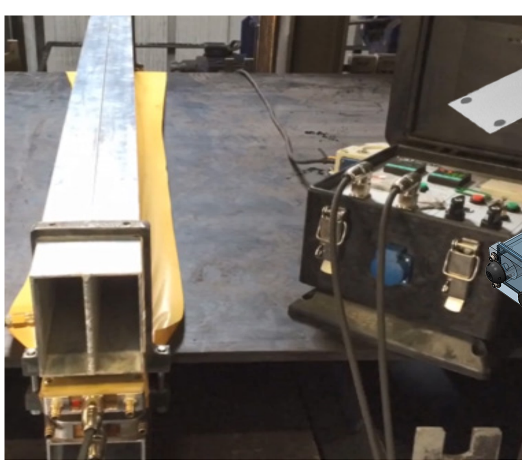


Fig. 4 Replacing Smartwires in the field.



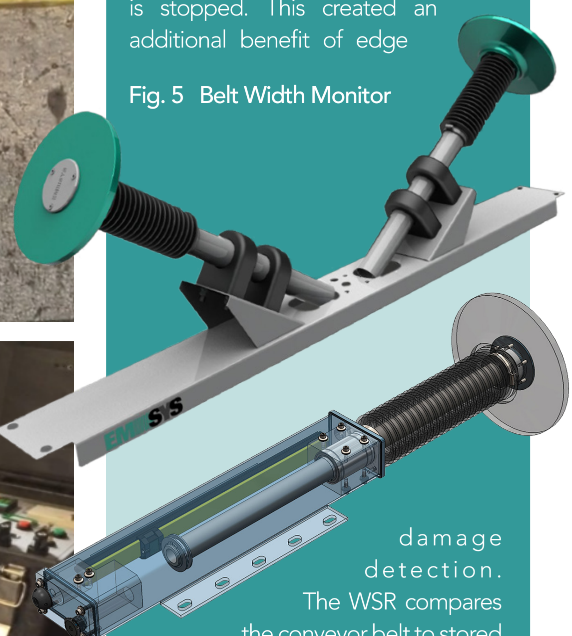
RIP DETECTION BASED ON BELT WIDTH

Systems that do not require antennae or panels to be installed in the conveyor belt are also desirable. Companies have tried ultrasonic systems, camera systems, and even simple systems that look for material spillage as an indication of a belt rip.

A new system in this class based on mapping and measuring the width of the belt, the WRS, has been developed by EMSYS. A single RFID chip is installed in the belt to identify a start position, a proximity sensor on the pulley is used to record the distance and a mechanical system is used to measure the belt width as it travels past a fixed point on the conveyor.

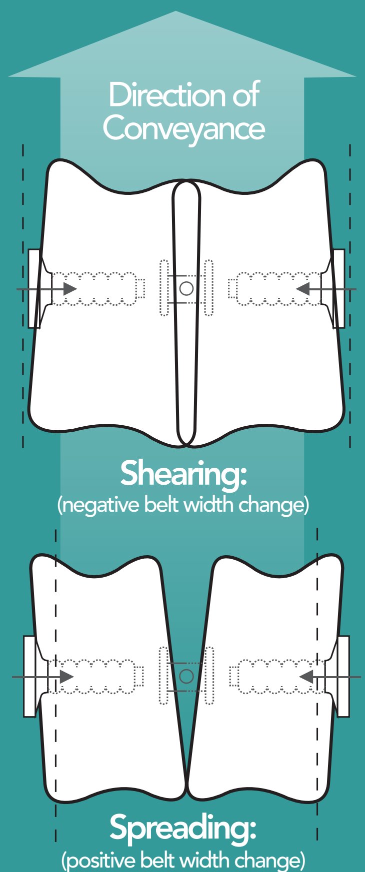
Any changes in the belt width compared to the stored pattern raises a belt rip alert and the conveyor is stopped. This created an additional benefit of edge

Fig. 5 Belt Width Monitor



damage detection. The WSR compares the conveyor belt to stored data and changes in the edge profile are detected. If the edge of the belt is newly damaged, changing the »

...RIP DETECTION



belt width, the conveyor will also be shut down.

To measure the belt width the positions of both the left and right edge are compared. This cancels out the belt tracking, as well as records the tracking signature of the conveyor.

When a conveyor belt is ripped due to a foreign object it will exhibit one of two different states – spreading or shearing. The WSR System utilizes an offset idler in front of the system to amplify these actions and accurately detect a rip.

Because the width-based system does not rely on antenna, it will detect a rip immediately after it begins due to the change in the width of the belt. As a result, less belt will be ripped with a width-based system than one with loops spaced intermittently throughout the belt.

RECOMMENDATIONS

Recommendations for rip detection system:

1. Transmitter and receiving heads are located on the conveyor system and in close proximity to the belt. The devices, connections and mounting bracket should be rugged enough to survive in the mining environment.
2. The control system is mounted near the conveyor system. It too should be rugged enough for the mining environment
3. At the location where the transmitter and receiver are mounted the tracking of the belt should be as consistent as possible and maintain constant contact with the adjacent idlers.
4. The system should be capable of working with different loop styles and RFID chips from various belt manufactures
5. The system should report and record the strength and history of each loop, tag or panel so that their life can be monitored over time.
6. The system should be accessible remotely, either in the office at the mine site, or over the internet to reduce the required access to the controller located at the conveyor system.

EMSYS
BELT ASSET MANAGEMENT

CONCLUSION

Advances in technology have improved the solutions for detecting rips is conveyor belts. Radio Frequency Identification (RFID) technology can now be applied to not only identify the location of a panel in the belt but also report on the condition of the antennae. This eliminates the need for large low frequency panels in the belt. The smaller size of the RFID based Smartwires significantly reduces the field installation time for new installations and replacements.

To help end users transition to the new Smartwire technology the transmitter and sensors heads are designed to read both the figure 8 and rectangular loop styles common in the marketplace.

For belts not initially manufactured with loops, or operators looking to add rip detection to their systems should consider the modern width-based system, the EMSYS WRS.