ADVANCES IN THE NON-DESTRUCTIVE TESTING OF CONVEYOR BELTING

G.J. Barfoot
TUNRA Bulk Solids Handling Research Associates
The University of Newcastle , Australia

1. SUMMARY

Non-destructive testing (NDT) of conveyor belting has become common practice throughout the world. This paper reviews some of the techniques used to date and discusses some advances in technology which has led to increasing applications of NDT systems for conveyor belting. Recent studies have demonstrated the value of simultaneous measurement of a number of a conveyors operational characteristics along with NDT of the belt itself. In addition, increased sensor performance and computer processing has resulted in better information from a simpler measurement process. This type of data has seen an increase in the capabilities of non-destructive testing for problem solving and maintenance programming in belt conveying systems.

2. INTRODUCTION

Comparison of the relative operating costs between a number of truck, rail and conveyor systems in Australia, shown in figure 1, demonstrates that conveyors are a cost effective method for transporting bulk material for distances up to 50km [1]. This cost advantage may be a factor in the low priority often given to programmed maintenance of conveyor belt systems. An operator running a fleet of ore trucks would not consider doing so without considerable expenditure on programmed maintenance and performance monitoring, yet belt conveyors are often operated using crisis management principals. The application of NDT and programmed maintenance, even to relatively small conveyors, can result in considerable cost savings.

As conveyor systems have become more complex, with speed, throughput and tension all steadily increasing, the capital cost of conveyor installations has gone up accordingly. This increased cost has seen a higher emphasis placed on obtaining the maximum operating efficiency from conveyor belt systems, part of this process has been the use of NDT. As the development of this equipment continues, the applications for its use have widened. High gain sensors and computer processing have seen an increase in the information derived from conveyor belt NDT while the measurement process itself has become simpler.

A conveyor system consists of a number of components, drives, take-ups, idlers and support structure, brakes, pulleys, loading and transfer points, horizontal and vertical curves and booster drives all contribute to the overall performance of the system. It is simply not possible to consider any component in isolation and while this paper deals primarily with the non-destructive testing of the belts reinforcing layer it is important to note that condition monitoring should cover all aspects of the conveyors operation.

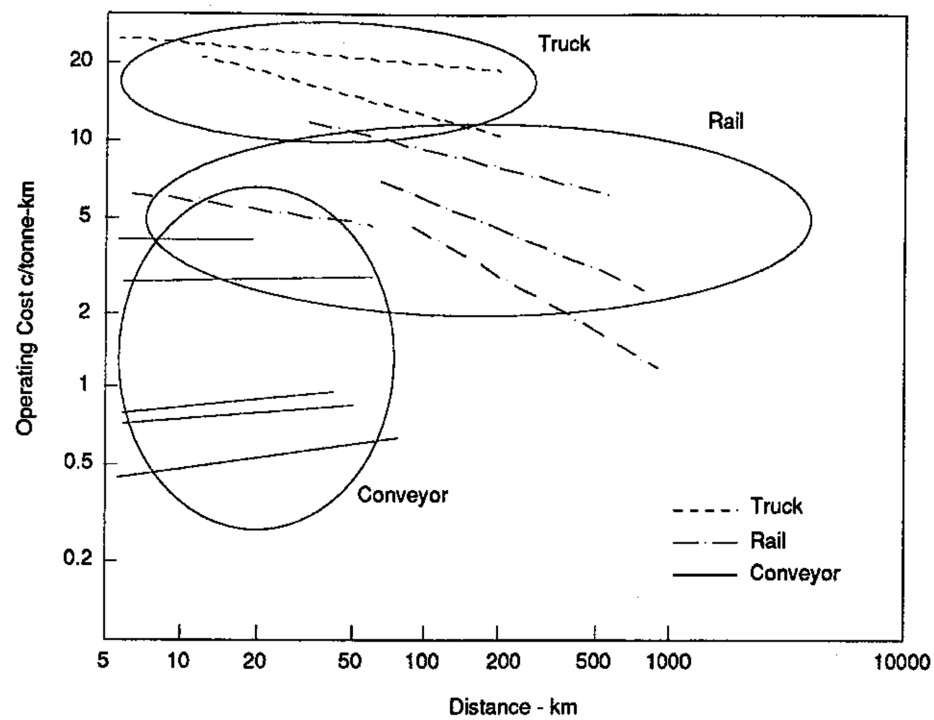

Figure 1 - Comparative cost of bulk material transport

A recent study by a NSW coal mining operation estimated the delays to production attributed to its belt conveyor systems amounted to 30hrs / month [2]. Based on a 24hr operation, this number represents what might be considered an acceptable availability, approx. 95%. However, if we apply this to lost production, at an average of 1000tph on the conveying system 30,000 tonnes/month amounts to 360,000 tonnes of lost production each year attributed to conveyor system downtime. If we note that 40% of Australia's exports come from the mining sector, a further significant amount from agriculture, and that a high proportion of all of those exports will at some stage pass through a belt conveyor system you start to get a feel for the potential cost savings through improved availability.

3. OBJECTIVES OF NON-DESTRUCTIVE TESTING

The objective for applying non-destructive testing varies between installations. Up until recently the main application for this technology has been with high priority belts, where stoppages will have a severe effect on operations. Regular condition monitoring has been used to reduce the possibility of unscheduled downtime. Current applications, however, increasingly involve one off problem solving where non-destructive testing is used to isolate a particular operational problem such as premature belt deterioration, regular splice or joint failure or belt tracking problems. As research into the use of monitoring techniques continues, conveyor belt operators are becoming more aware of the possibilities of using this equipment to improve the availability and reliability of their belt conveying systems. It is important to realise that damage to the conveyor belt is usually a symptom of other problems. Conveyor system operators have been using NDT as a measure of the performance of the conveyors operation and maintenance programs. Utilising NDT to identify and eliminate problems which are wearing or damaging the belt will ultimately lead to condition monitoring being necessary only as a check on performance. Much in the same way as measurements and controls are used to maintain a quality assurance system.

To achieve greater productivity, three main areas can be targeted using condition monitoring.

- Reduce Maintenance Costs
- Reduce Downtime
- Increase System Life

Reduce Maintenance Costs

Most belt conveyor operators will have some sort of maintenance program for their conveyor systems. It will generally include manpower for repairs, visual inspections and clean up operations as well as spare parts such as idlers, idler frames, pulleys, belting and splice kits. On conveyors which generally provide few problems the maintenance budget may be relatively low and application of condition monitoring on a significant scale may not be justified. In many cases, however, the annual maintenance budget for the conveyor far exceeds the cost of a condition monitoring program. The main cost savings to be made are in the reduction in labour for major repairs and inspections, reduced spillage and a smaller spare parts inventory. Precise data regarding the condition of the belt will enable more accurate estimates of the amount of belting required in stock to deal with belt replacement requirements.

Reduce Downtime

The cost of downtime can be extremely high, in an economic climate where many operations are only just viable, unscheduled stoppages can mean the difference between profit and loss. In many cases, if condition monitoring can reduce downtime by as little as 1 hour over the period of the measurement (this may be 6 or 12 months), the cost of the measurement is recouped. Any reduction in downtime after that is a cost saving to the operator.

Increase System Life

A steel cord conveyor belt system could be expected to last approximately 10 to 15 years, life spans for fabric belts vary with the application but a figure of 5 years is quite common. This can be significantly shortened by a number of unsatisfactory operating practices particularly incorrect material loading and failure to quickly repair damaged belt covers. Condition monitoring will highlight the existence of such problems before they reduce the life of the conveyor. A conveyor on the NSW south coast has been running for over 20 years with the use of condition monitoring playing a significant part in its continued reliable operation. With a replacement cost in the millions of dollars the cost saving to the operator of extending the life of this conveyor is significant.

Common Belt Conveyor Problems

Some of the types of problems that condition monitoring can help reduce or eliminate are :

- Failure of joints or splices

  Achieving high quality joints and splices in the field is a difficult task and often these are the weakest point in the belt. Combined with poor starting and stopping practices joint failure is a major problem for many conveyor installations.

- Failure in parent belt

  Can result from minor damage going unrepaired for a long period of time, the belt reinforcing layer eventually deteriorating to the point where the strength of the belt is compromised. Position and condition of the reinforcing layer during manufacture is also important and can be checked with NDT.

- Belt mis-tracking

  Alignment of splices and position of the reinforcing layer in the rubber play a significant role in how the belt tracks. Tracking can also be affected by damage to the reinforcing layer.

- Premature belt, idler or pulley wear

  An uneven distribution of tension in the reinforcing layer has been known to produce speed differentials across the width of the belt. The resulting accelerated wear of pulleys and idlers is often extremely high.

In many cases, the main purpose of the belt monitoring is to provide accurate, quantifiable data on the belts condition. Based on this, the source of a particular problem can often be identified and a strategy for belt replacement or repair can be established.

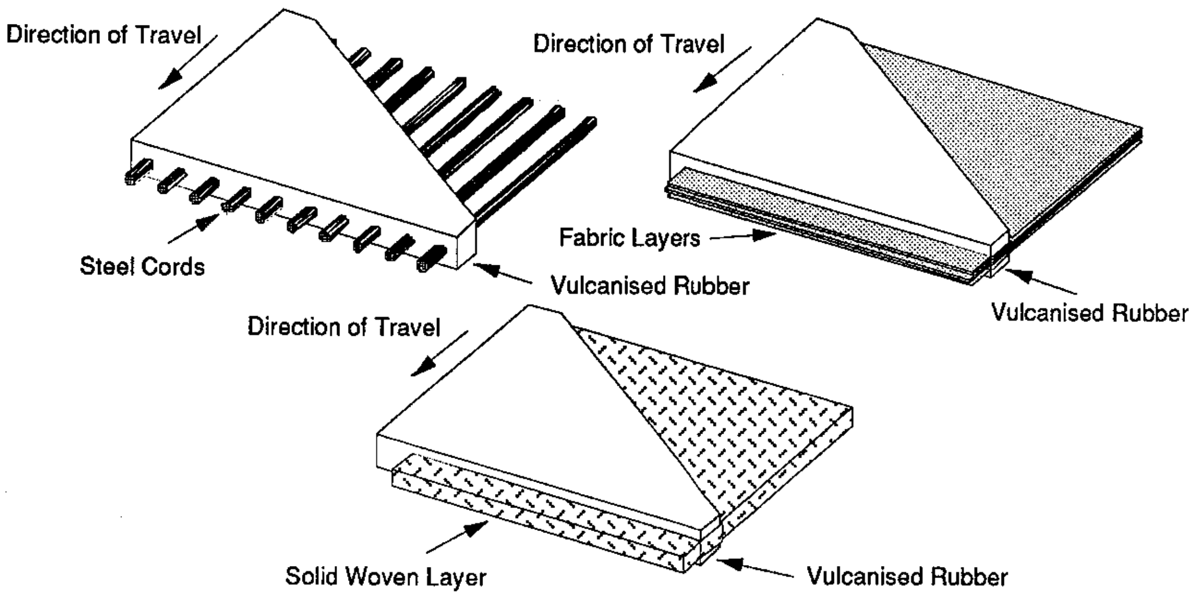

Figure 2 - Typical Belt Constructions

4. NDT TECHNIQUES

Figure 2 shows three of the most common types of conveyor belt. Conveyor belt is normally constructed from a high strength material vulcanised inside a rubber compound. The main area of concern when discussing condition monitoring is the high strength material, often referred to

as the reinforcing layer. So the fundamental requirement for any condition monitoring equipment is the ability to detect the condition of the belts reinforcing layer by penetrating the surrounding rubber compound.
In addition to this basic design criteria, attention must be paid to the conditions under which the non-destructive test equipment will be required to operate. Invariably conveyor belts exist in harsh environments, often the measuring equipment needs to be transported long distances to get to site and then may be carried by hand some distance underground or over rough terrain. Power supply may not be available. intrinsic safety may be an issue for underground work and minimal interruption to normal belt operations is very important in gaining access to the conveyor over the operators production commitments.

On top of all these issues, the reliability of the equipment is crucial. In many cases, the cost of getting to site to conduct the measurement exceeds the value of the instrumentation, there is no room for equipment failure. The formula which has been used successfully is to keep the equipment simple, it must be non-contact and there must be a back-up plan for the failure of any component in the measurement process.

There are a multitude of methods, devices and configurations which can be utilised for conveyor condition monitoring. For a particular application, one or a number of these techniques may be employed to obtain the required information.

4.1 Steel Cord Monitoring

The most suitable methods for detecting the condition of steel cords are electromagnetic, the fundamental reason being the rubber is usually invisible to these type of sensors. The most common methods for NDT of steel cord conveyor belting are listed below.

- Inductive
- Reluctance
- Induced Voltage
- Eddy Current
- X-Ray
- Ultrasonic

Discussion here will be limited to the first three techniques. Eddy current and xray methods have been applied to steel cord belts in the field by others with a good deal of success. Eddy current devices, however, require more complex processing than the methods currently used by the University of Newcastle and on this basis are not in general use at this time. Xray techniques provide accurate data on the steel cords but it is a time consuming process more suitable to detailed analysis of a single area than to monitoring of the whole belt. Xray video equipment used on a number of sites requires the belt to be run at low speed and produces hours of tape which must analysed manually.

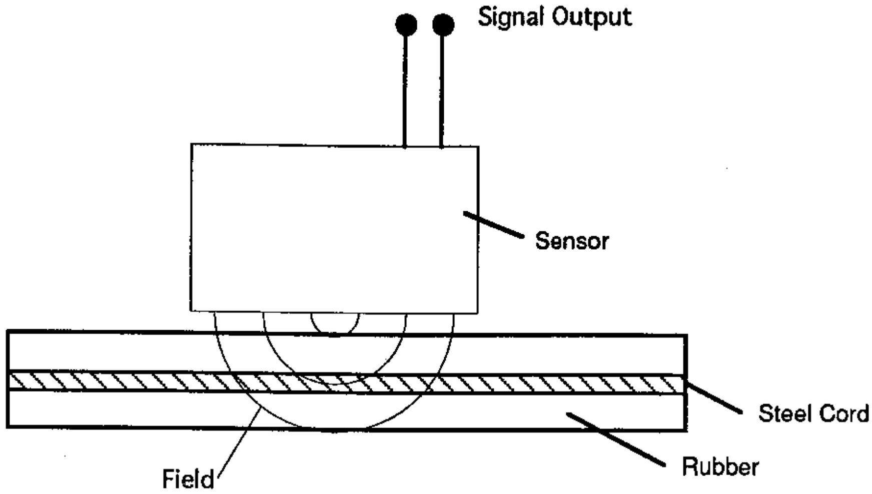

Figure 3 - Active NDT Sensor for Steel Cord Conveyor Belting

The sensor illustrated in figure 3 is referred to as an active sensor. It generates a field which encompasses the steel cord reinforcing layer of the belt. This type of sensor is well suited to measuring the position of the cords within the belts cross section and determining the mass of steel at a given belt cross section. This is particularly useful for detecting areas of corrosion.

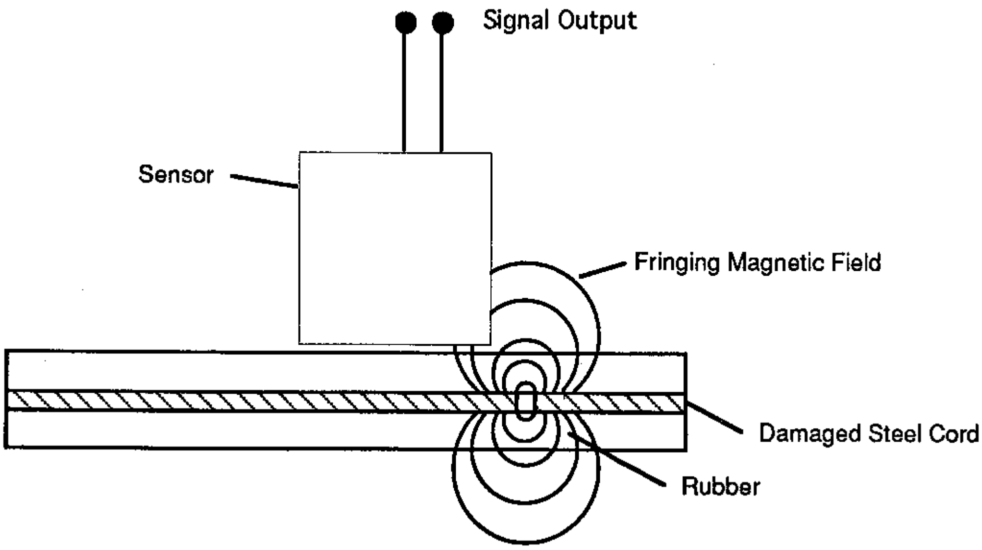

Figure 4 - Passive NDT Sensor for Steel Cord Conveyor Belting

Passive sensors ,shown in figure 4, utilise the magnetic characteristics of the steel cords to detect very small changes in the reinforcing layer. The ability of this type of sensor to detect cord damage of only a few strands have made this measurement the most widely used of current condition monitoring techniques.

4.2 Fabric and Solid Woven Monitoring

Condition monitoring of fabric and solid woven belting is more difficult than measuring steel cords. The techniques available will invariably be sensitive to the condition of the rubber covers as well as the reinforcing layer. Methods which have been applied to this type of belting include :

- Capacitive
- Ultrasonic
- Xray

Of these, capacitive sensors have proven to be the most reliable. The slight difference in density between the rubber compound and the reinforcing layer is not always sufficient to produce good quality xrays and ultrasonic transmitters and receivers often lack the sensitivity to achieve the required penetration through the rubber. The capacitive sensor is an active device which generates a high frequency field. The magnitude of the field is a function of the belt characteristics and any changes in the belt or reinforcing layer produce variations in the sensor output.

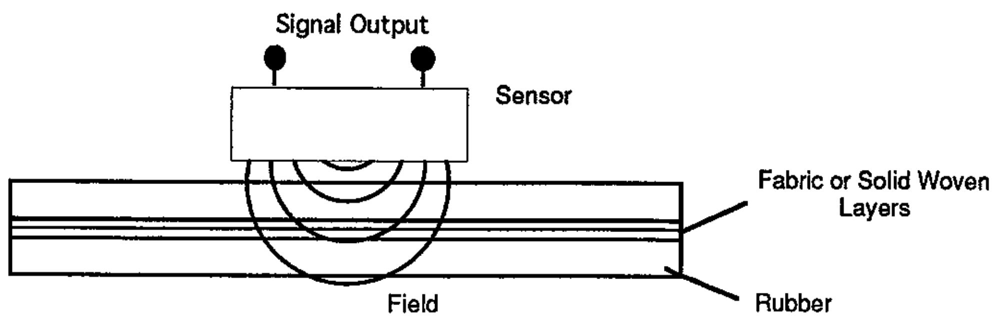

Figure 5 - Active NDT Sensor for Fabric or Solid Woven Belt

5. NDT Signals

5.1 General Measurement Principals

All of the sensors used by the University of Newcastle are modular, lightweight units designed to be carried by one person. The equipment has been kept simple and to a minimum, the signals are recorded on data recorders, the processing and analysis is performed back at the laboratory. The modular sensors can be cascaded end to end to accommodate any belt width, the small units used for cord plane measurement can be used hand held or on a motor driven carriage. As a general concept to analysis of the signals, a perfect belt would produce a constant output from the instrumentation, any deviation in the signal represents some change in the belts properties or condition. Figure 6 shows a typical system configuration for conveyor belt NDT.

5.2 Steel Cord Conveyor Belting

Most of the NDT up to this point has been concentrated on steel cord conveyor belts. The main reason for this is that steel cord belting is significantly more expensive and is generally used on larger, more complex conveyor systems where performance and reliability are of utmost importance.

Measurements conducted on steel cord belts have had one or more of the following objectives :

- Locate and monitor the deterioration of all damage and corrosion in the steel cords throughout the belt.
- Look for signs of deterioration in splices.
- Isolate and quantify a particular problem.
- Measure the profile and wear rate of the rubber covers.
- Determine the position of the steel cords in relation to the overall cord plane.

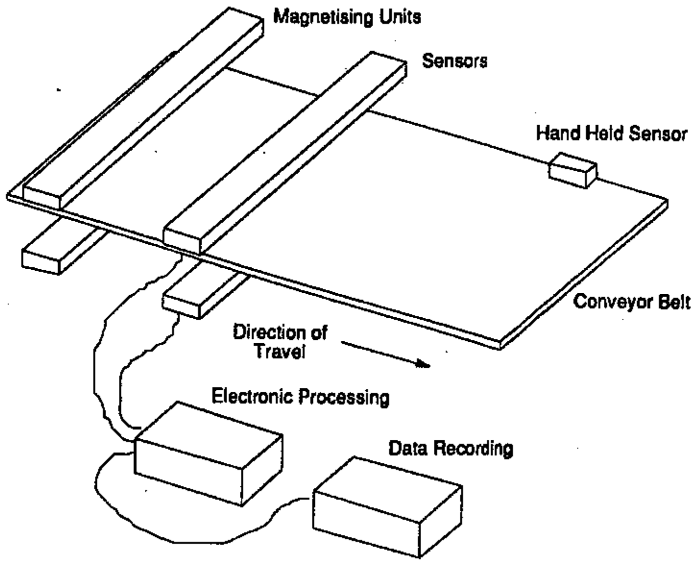

Figure 6 - Conveyor Belt Condition Monitoring , System Setup

Damage and Corrosion in the Steel Cords

When considering the condition of the steel cords in the parent belt, three items are usually of importance :

- How much damage ? (ie. how many cords involved)
- Where is the damage located ?
- Is it deteriorating or is it stable ?

The broader question of what effect the damage has on the belts operation usually requires further analysis, often involving computer modelling and simulation.

In the majority of cases, damage in the steel cords is the result of the rubber cover being penetrated and moisture gaining access to the cords. Once the cords begin to corrode, the chemical reaction can cause delamination of the covers and the moisture can spread to other cords. If the effected area is not repaired a large number of cords can corrode to the point where the strength of the belt is severely compromised. Another major cause of cord damage is the failure of the rubber covers at cover joins. Once the cover has opened up at the join, the ingress of moisture quickly starts the corrosion cycle. There have also been a number of examples of cords failing due to fatigue, usually the result of being positioned outside the nominal cord plane.

Figure 7 shows the some of the signals produced by damaged or corroded steel cords. The top trace is an active sensor measuring the mass of steel present at any given cross section. The large spike is a splice, where as expected the amount of steel is significantly greater than the rest of the belt. The step in the signal which follows the splice shows where an edge cord has been ripped off resulting in a reduction in signal level equivalent to one cord. The bottom trace is a passive sensor, once again the large signal is the splice, the smaller signals show cord damage of various magnitudes. The amplitude of the signal is proportional to the magnitude of damage, the location of the site can be determined by measuring the distance from the splice signal and scaling up by an amount calculated from the belt and chart speed.

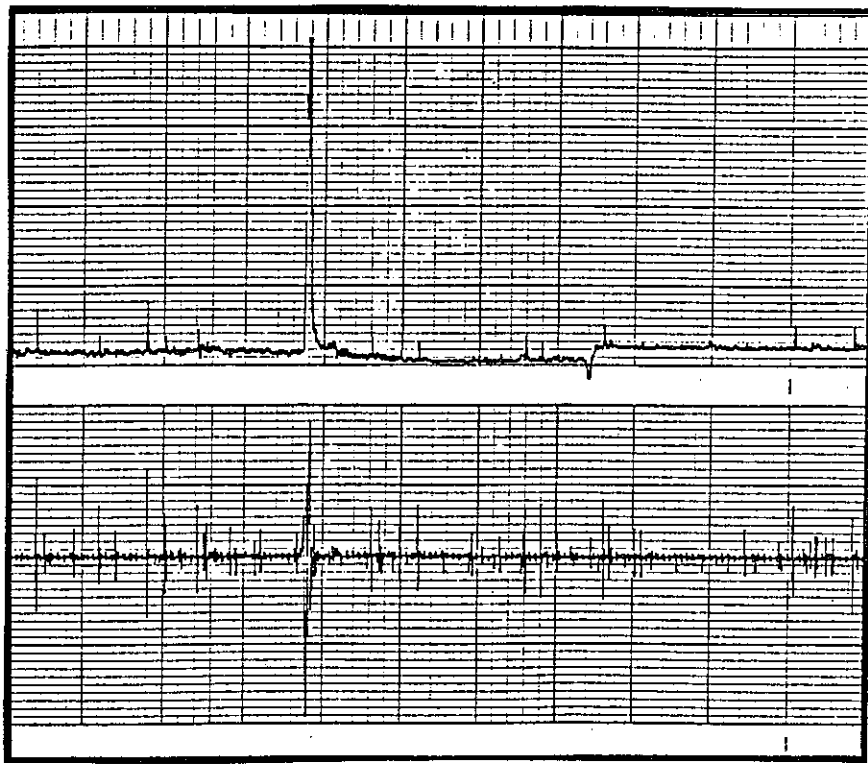

Figure 7 - NDT Signals from Damaged and Corroded Steel Cords

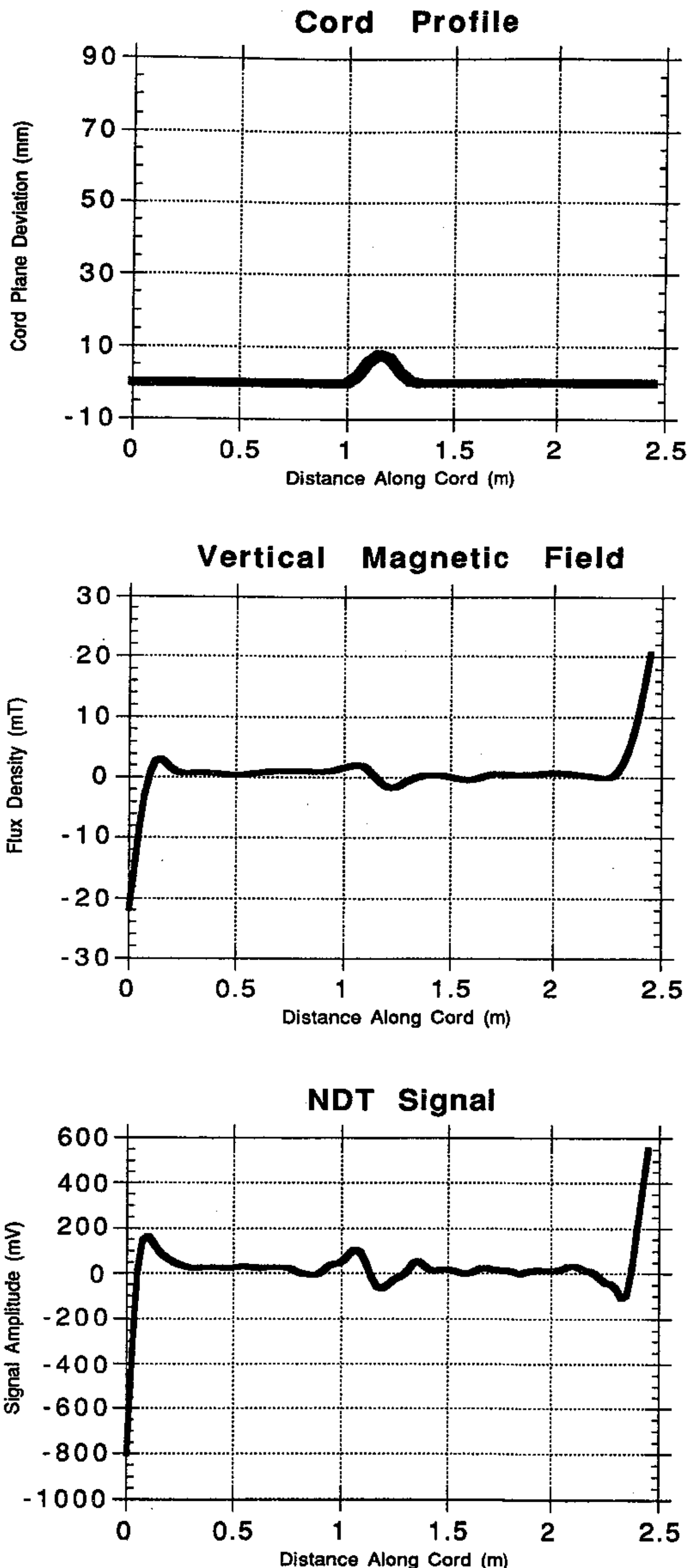

Figure 8 - Characteristic NDT signal for cord plane deviations

High Gain Passive Sensors

Advances in the design of passive NDT sensors for steel cord belts has enabled detection of cord plane anomalies which until now have been difficult to measure. The new sensors can detect the variation in the field of steel cord which is undamaged but is out of position in the cord plane. Figure 8 shows a laboratory test to evaluate the sensors where the position of a steel cord has been varied by 10mm over a distance of 250mm. As the graph shows the slight change in the cords field is readily detected by the sensor. Figure 9 is field data of cord plane deviations occurring at regular intervals in a steel cord conveyor belt.

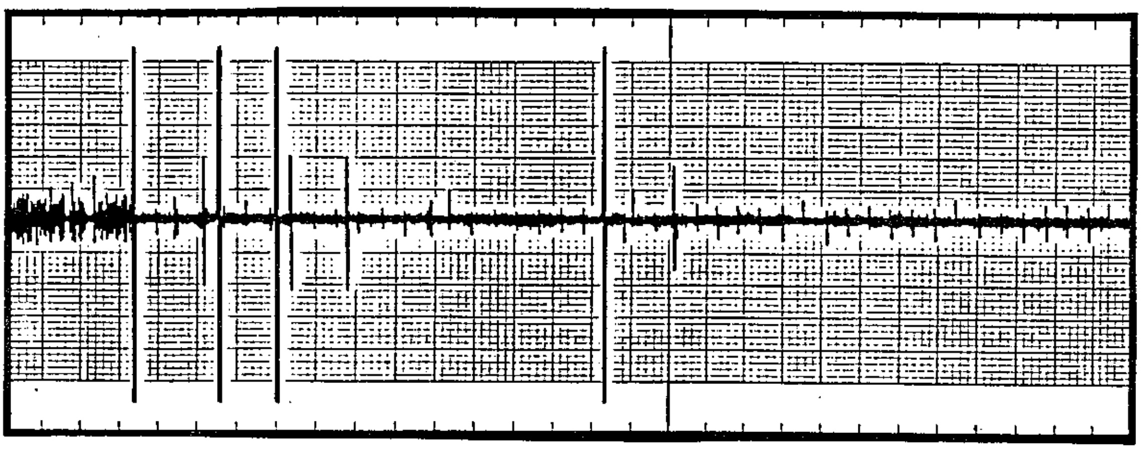

Figure 9 - Field measurements showing regular cord plane deviations

5.3 Fabric and Solid Woven Conveyor Belts

The principle use of NDT techniques with fabric and solid woven belting has been to determine the worst area's of a particular belt in order to program the required maintenance. With belts where the amount of replacement is significant these measurements have been of great benefit to simply keeping track of the repairs. The monitoring equipment can be used to generate a belt "map", accurately laying out the number of joints and where they are located. This type of information has proven invaluable to planning stock levels and maintenance crew requirements.

Application of other measurements, belt acceleration, motor currents and belt tensions have been successfully combined with the capacitive sensors to reduce or eliminate problems with belt and joint failure on start-up, belt tracking or drive slip.

Figure 10 shows the signal from an active sensor mounted on a fabric belt, the constant signal produced by belt in good condition can be seen clearly. The large deviations in signal are caused by a number of different belt damage conditions.

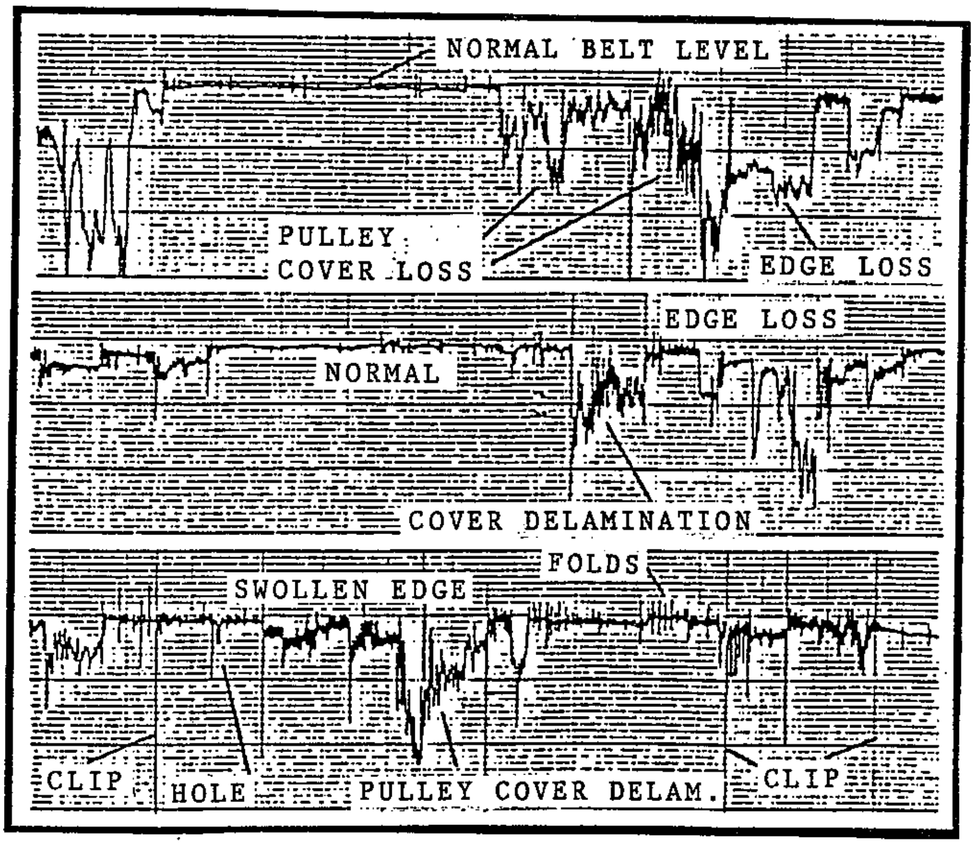

Figure 10 - NDT signal from an active sensor measuring a fabric belt

6. NDT OF STEEL CORD SPLICES

Splices are used in steel cord belts to join manufactured lengths during installation, to replace sections of belting and to repair extensively damaged belting. While the theoretical strength of the splice can be equal to that of the belt, generally fatigue and other conditions will mean the splice often represents the weakest section of a conveyor.

6.1 Steel Cord Splice Construction

A steel cord splice is constructed by interlaying the steel cords of each section as shown in Figure 11, adding rubber above, below and between the cords and then vulcanising. While in operation the belt tension is transmitted from one section to the next by the shear strength of the rubber between the cords. The higher the expected belt tension, the greater the length rubber required to transmit the forces and the longer the splice will need to be.

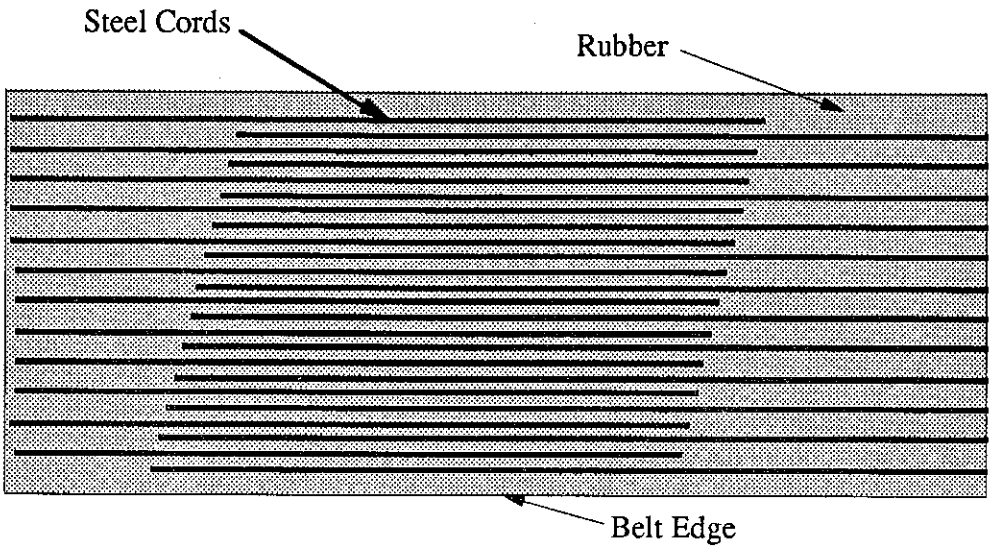

Figure 11 - Steel cord splice construction , stage 1 splice

6.2 The Mechanism of Tension Transfer

When a steel cord splice is subjected to an increase in tension the length of the steel cord overlap decreases by a small amount. This decrease in length is a result of the rubber deforming in shear. The actual change in length for a particular splice will depend on a number of factors including the number of cords, cord diameter, cord spacing, applied load and the shear characteristics of the rubber. Figure 12 shows the relative movement of cord ends when the splice is subjected to tensile load. Cord movement of between 1mm and 2mm has been observed in splices subjected to operational tensions.

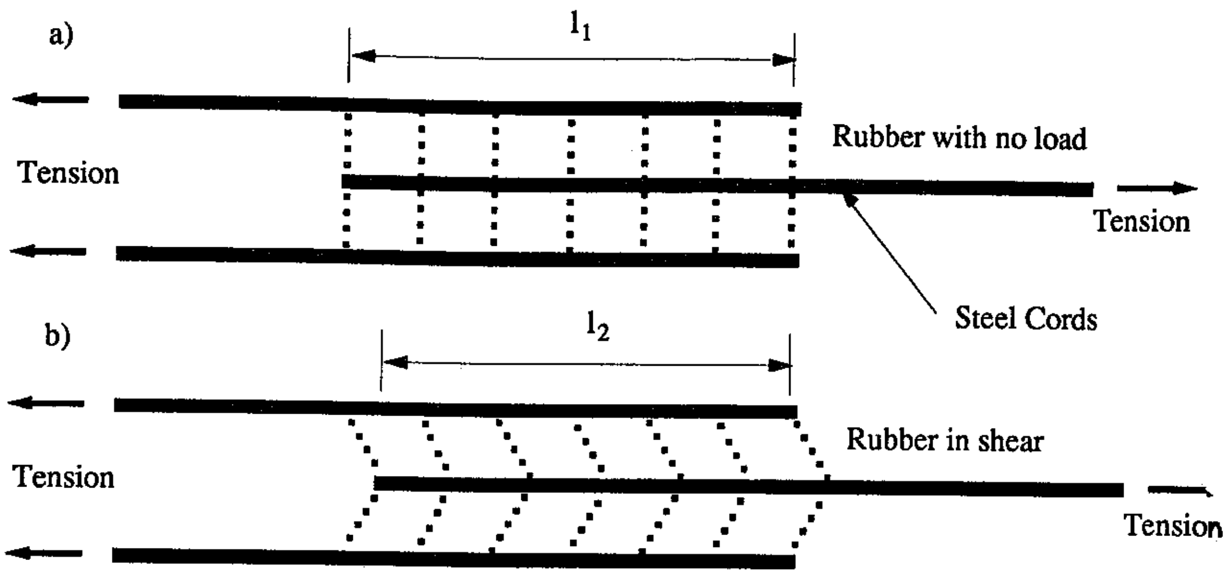

Figure 12 a. Steel cord splice with no load
b. Steel cord splice under tension

6.3 Current NDT Techniques

Visual Inspection

The most common method of checking splice condition is by visual inspection. Irregularities in the surface of the conveyor belt are normally an indication of adhesion problems. Bulges in the belt surface are frequently caused by cords with poor adhesion pulling back from the splice under tension then not being able to return to position as the rubber encroaches on the void left at the end of the cord. Dimples appear at the end of a cord where adhesion along the cord is poor but good at the cord end. Frequently, however, these indications are most prominent in sections of the conveyor where access is poor and the speed of the belt make visual inspections an unreliable method of detecting a failing splice.

Grid Line Method

A technique for measuring adhesion loss in steel cord splices was described by Harrison in 1983 [9]. It involves marking out an accurate grid on the surface of the belt in a low tension area of the conveyor. The splice is then run up to a high tension area and the distortion of the grid measured. This distortion gives a direct indication of the splices load sharing characteristics.

While this method produces good results, it is limited by the need to stop the conveyor and the fairly time consuming process of marking out and measuring the grid. In the event of a particular splice being regarded as suspect by other methods the grid line technique could provide accurate information on that splice.

Bulge Detection

The mechanism which causes the steel cords in a failing splice to bulge is described in some detail by Harrison [9]. For the purposes of this paper it is sufficient to recognise that the bulging of cords in a splice is a common indication of imminent failure. Detection of such a bulge by various means, some of which are shown in Figure 13, can be utilised to shut down the conveyor prior to a splice failure.

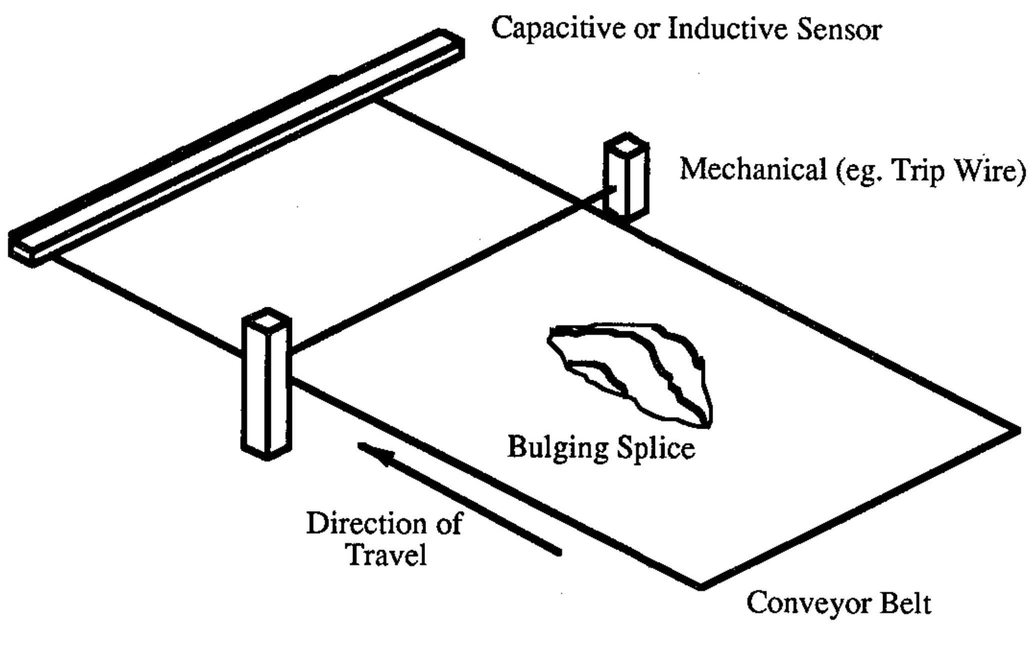

Figure 13 - Methods of Detecting a Bulging Splice

X-Ray

X-Ray techniques are well suited to evaluating steel cord conveyors including the splices. Recent advances in x-ray equipment, in particular the running x-ray recorded on video, have increased the applications for this technology in the area of belt condition monitoring. Close inspection of the x-ray of a steel cord splice can reveal areas of poor adhesion between the rubber and the steel cords. This measurement, however, generally entails stopping the conveyor or at least moving it at low speed for each splice. The analysis of the results is time consuming and requires some expertise.

Impact NDE

A method of determining the adhesion between cords and rubber through variations in the stress velocity through the belt was outlined by Harrison in 1989 [10]. By strategically attaching accelerometers to the belts surface, the speed of a stress wave induced on one side of the splice can be measured. Harrison showed that a non-uniform distribution of speed as measurements are conducted across the belt indicate problems with adhesion or cord placement. This test method has been primarily used for analysis of belt splices in the laboratory.

Magnetic Signature Analysis

Non destructive testing of steel cord conveyor belts through the analysis of magnetic signatures is a well established practice. Application of this technique to conveyor belt splices can provide accurate information on splice construction (Harrison, 1985 [11]), but so far has not yielded a proven method of determining the integrity of a splice. Trends regarding the de-magnetising of the steel cords as a result of cord movement have been observed during a number of field measurements. These trends occur over some period of time and the likelihood of a splice failing in between a series of measurements is high. Difficulty has also been experienced in magnetising the steel cords of a splice where significant movement is taking place. While this is an immediate indication of poor adhesion, only a small percentage of splices exhibiting this characteristic have been known to fail. This could be regarded as a result of sufficient safety factors being available in most installations to tolerate some adhesion breakdown in the splices. The main problem with this analysis is that a splice suffering from a breakdown of adhesion will not always exhibit these characteristics during the magnetising process.

6.4 A New Application of Magnetic Signature Analysis

A splice with a significant area of poor adhesion will not share load uniformly across the width of the belt. This measurement technique evaluates the load sharing characteristics of a splice without the interruptions to normal operations of some of the methods discussed so far and has the potential to provide accurate information on the splice's integrity.

The measurement technique present here is a variation of magnetic signature analysis but the emphasis is on the change in the signature as the splice passes from high tension to low tension.

<u>The Field around a Magnetised Splice</u>

A magnetised steel cable has a field similar to a bar magnet. One end will be a north pole, the other a south and the field will fringe outside the cord at the ends and at any damage or buckle along the cords length. Of interest in splice analysis is the fringing at the cord end. The magnetic field intensity at the end of the cord is of a useable magnitude up to 200mm from the cord and 300 to 400mm down the cord from the end depending on the level of magnetisation.

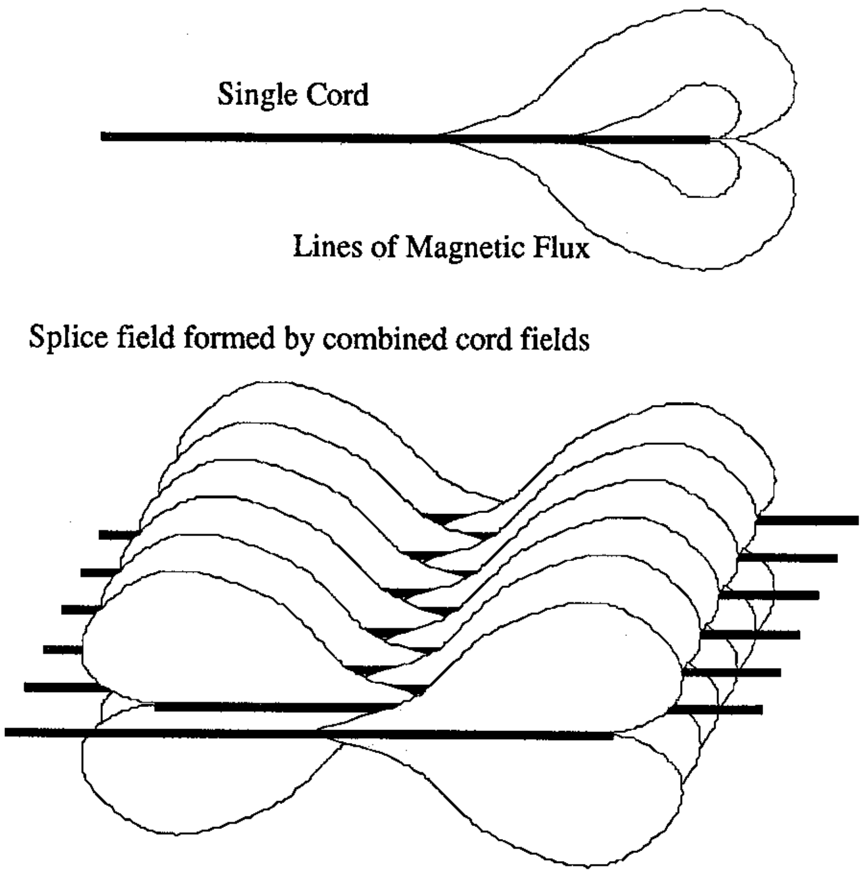

Figure 14 - Simplified view of the magnetic field around a splice

The magnetic field around a splice is a composite of the fields generated by each cord. Figure 14 gives a simplified view of how the field of a splice is constructed. In reality the overall field will be more complex as the magnetised cords interact with each other but the diagram gives an indication of how the cord end positions determine the field shape.

Field Distortion from Non Uniform Load Sharing

Work by Harrison showed a cord in a steel cord belt which does not share load puts a higher stress on the adjacent cords. This uneven load equalises over a number of metres of belting by cord elongation (see figure 15). It is this difference in elongation of a non-load sharing cord which results in a slight difference in the position of the cord ends in a splice.

Having established that the end of a cord which is not sharing load will be out of position, the effect of this on the splice's magnetic field needs to be examined. Clearly a single cord out of position by as little as 1mm will have a minimal effect on the magnetic field around the splice. In order to reach detectable levels, a number of cords will need to be out of position. The sensitivity of the measurement is a function of the number and size of sensors. As a general guide, the section of splice not sharing load will need to be as wide as a single sensing element for reliable detection.

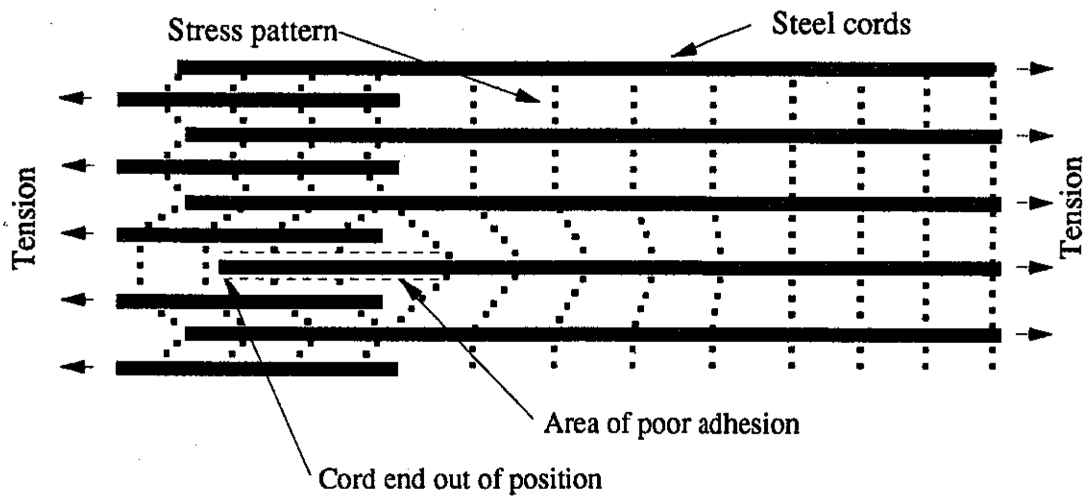

Figure 15 - Steel cord movement resulting from uneven load sharing

6.5 The Measurement Technique

Detecting the Magnetic Field

Figure 16 shows the arrangement of the sensors for the carry and return strand of the conveyor and Figure 17 is a typical splice signature for a single section of the splice. The A sensors are located on the carry side before the drive or at a suitable location in a high tension area. The B sensors are positioned near the take up or a low tension area. The change in the direction and magnitude of the magnetic field as splice passes is detected by the sensors and produces a signal which is processed and recorded for later analysis. The arrangement shown in Figure 16 divides the belt into six equal sections and would require 12 recording channels.

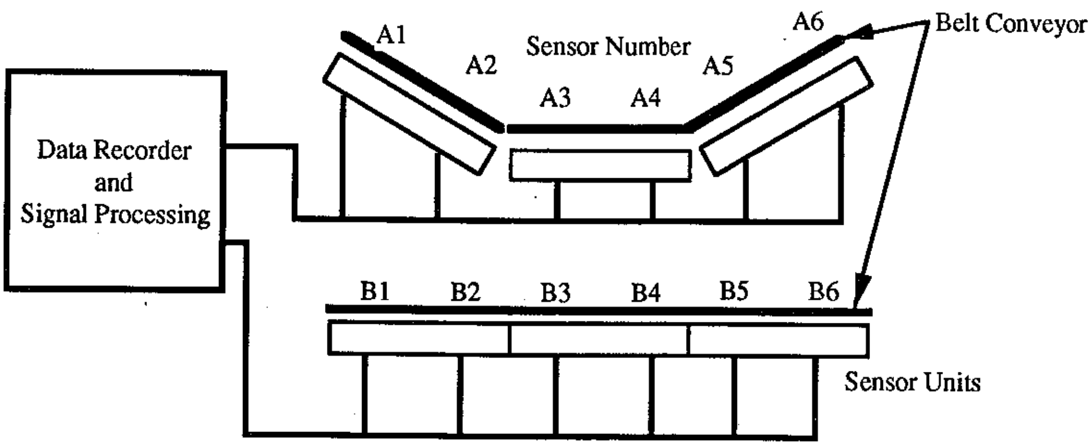

Figure 16 - Sensor arrangement for magnetic field detection

Data Analysis

This measurement technique requires computer aided analysis of the data. Fitting sensors to one side of the belt only in different areas of the conveyor make it difficult to match the results from the A and B sensors. This combined with variations in belt tracking mean that averaging is required in interpretation of the data.

By dividing the width of the conveyor into six sections the minimum resolution of the measurement is an area of adhesion loss equal to 1/6 the belt width. Given that most conveyors are designed with a safety factor of between 6:1 and 10:1 the minimum resolution of the measurement is well below the failure point of the splice. It should be kept in mind that the aim of the measurement is to highlight splices with abnormally high distortions in tension distribution as potential belt failure points.

The signal produced by each sensor is a function of the magnetic field surrounding that section of the splice. As this field is directly effected by the position of the cord ends, the signal can be used evaluate cord end movement. A uniform change in the signal from each sensor as the splice moves from high tension to low tension would indicate uniform cord end movement and uniform load sharing.

The data is analysed by comparing the distance between the peaks of the signals for each section of the belt as the splice passes from high tension to low tension. For example, the signals for a particular splice from sensors A1 and B1 (see Figure 16) are fed into the computer, normalised and displayed on the same screen. The distance between the peaks for each signal is noted. A perfect splice would give the same signal variation for each pair of sensors, 1 through 6, covering each section of the splice.

The technique of comparing the signals for the splice in high and low tension allow any irregularities resulting from splice lay up or the effect on the magnetic field of the conveyed material to be dealt with during the data analysis. The measurement information is contained in the signal variation and the errors are eliminated during the computation.

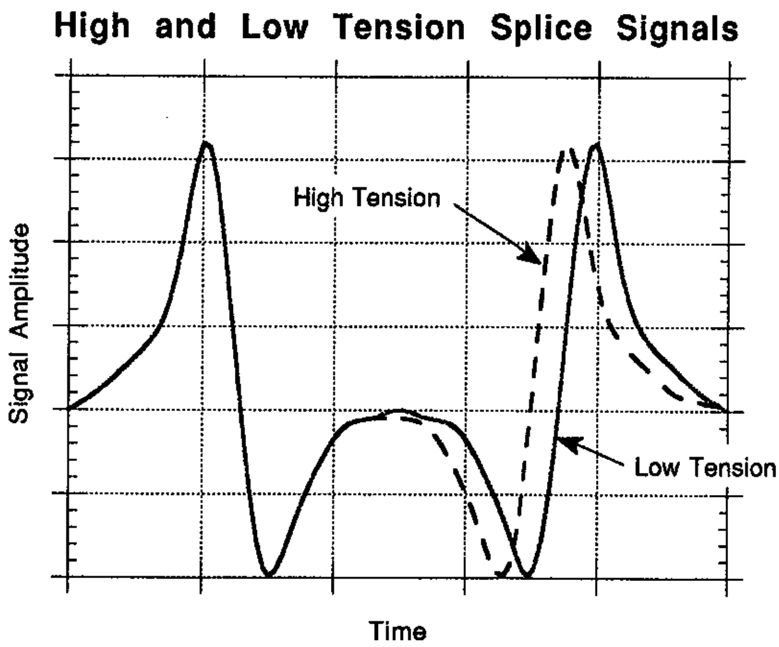

Figure 17 - Difference between splices signals taken in high and low tension

Using the signal variation the movement of the cord ends can be determined. This combined with the rubber and cord characteristics can be used to calculate belt tension for each section of the splice.

7. SIGNAL ANALYSIS

NDT signals from conveyor belting are complex and typically require some expertise for interpretation. Development of analysis software has the potential to enhance the presentation of data obtained from NDT as well as reducing the reliance on the ability of the operator during the analysis phase. The long term aim is an expert system which can be permanently installed on a conveyor system and deliver information on the belts condition without the need for lengthy, manual interpretation of signals.

The first step in this process is the development of programs to assist in the analysis and presentation of NDT signals. Current software can read field data from the recorder and quickly quantify the magnitude and location of all relevant signals. This information can then be presented in a number of ways depending on the requirements. Figure 18 shows the damage density along the length of a particular conveyor. The computer calculated the number of NDT signals above a certain threshold for every 50m of belting. The result is an indication of which sections have the highest number of damage locations, which in this case did not coincide with the largest magnitude locations shown in Figure 19. The operator can now program to repair the largest magnitude locations and replace the sections of highest damage density.

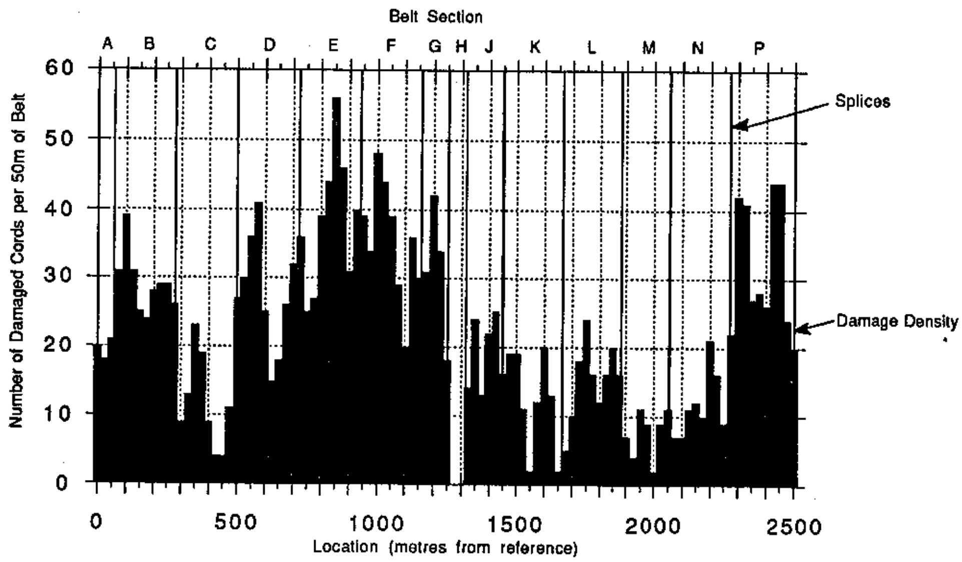

Figure 18 - Computer generated data on damage density along a conveyor

Once the data is in the computer many other forms of analysis can be quickly evaluated. Separating the number of damage locations on the left and right side of the belt has been used to identify problems with loading. A particular section of the belt, for example the belt edges, can be isolated to look at specific problems. A belt which is mistracking can have a tracking measurement combined with data on the belt condition to assist in identifying the cause of the mistracking. A particular signal can be expanded on the computer for detailed analysis, this could include splice signals or large magnitude damage locations.

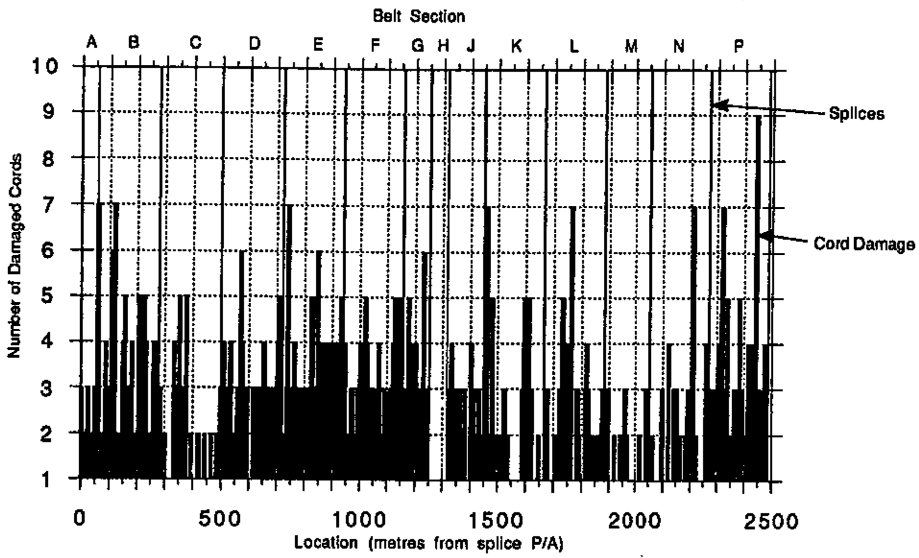

Figure 19 - Computer generated data on damage magnitude along conveyor

8. CONCLUSION

As development of both sensor technology and signal analysis techniques continues the role of NDT of conveyor belting will expand. Already we have seen stringent tolerances placed on manufactured belting in regard to steel cord position. Such tolerances can only be measured and controlled with the assistance of NDT. The use of NDT in the field has been and will continue to be a valuable tool in the operation and maintenance of belt conveyor systems. The application of NDT for belt conveyor research will lead to better understanding of conveyor characteristics and improved design and construction procedures. This paper has outlined some of the areas of advancement and research which are currently underway at the University of Newcastle.

9. REFERENCES

1. Roberts, A.W., Harrison, A. and Hayes, J.W. Economic Factors Relating to the Design of Belt Conveyors for Long Distance Transportation of Bulk Solids, Bulk Solids Handling, Vol. 5, No. 6, Dec 1985, pp 1143-1149.

2. Pomfret, D. Realising Maximum Production Potential with Safety, Engineering Safety Seminar, Dept. Mineral Resources NSW, Penrith, May 1992.

3. Harrison, A. Predicting the Tracking Characteristics of Steel Cord Belts, Bulk Solids Handling, Vol. 10, No. 1, 1990, pp 47-53.

4. Harrison, A. Stress Distribution in Steel Cord Belts with Cord Plane Defects and Inlaid Repairs, Bulk Solids Handling, Vol. 8, No. 4, 1988, pp 443-446.

5. Harrison, A. A New Development in Fabric Belt Monitoring, Bulk Solids Handling, Vol. 8, No. 2, 1988, pp 231-234.

6. Kwun, H. and Burkhardt, G.L., Nondestructive Measurement of Stress in Ferromagnetic Steels using Harmonic Analysis of Induced Voltage, NDT International, Vol. 20, No. 3, June 1987, pp 167-171.

7. 1990 Conveyor Belt Engineering Workshop, Goodyear Tyre & Rubber Company.

8. Harrison, A., A new technique for measuring loss of adhesion in conveyor belt splices, Aust. J. Coal Min. Tech. Res., No. 4 (1983). pp 27-34.

9. Harrison, A., Examination of Adhesion Failure in belt splices by impact NDE, Proc. Composites Asia Pacific Congress 1989, Adelaide, Vol. 2, pp 542-553.

10. Harrison, A., Testing steel cord belt splices with a magnetic conveyor belt monitor, J. Non destructive Evaluation, Vol. 5, No. 1, 1985, pp 15-19.

11. Lubrich, W., Theoretical Analysis of the Tensile Strength of Steel Cable Conveyor Belt Joints, Brunkhole, Warme und Energie, Vol.12, Nov 1960, pp. 503-513.

12. Harrison, A., Performance of Corded Composites with Damaged and Misaligned Reinforcement, Proc. Composites Asia Pacific Congress 1989, Adelaide, Vol. 2.