Development of a System for the Measurement of the Dynamic Belt Tension Distribution On an Operating Conveyor Belt.

W.F. Madden BE GradIEAust - Professional Officer, Institute for Bulk Materials Handling Research. University of Newcastle, Callaghan NSW Australia

1. ABSTRACT

This paper reviews a method developed for the determination of the belt tension distribution during operation of a conveyor belt. A test rig using three standard idlers mounted on six load beams enables the measurement of force vectors resulting from an induced belt displacement. Analysis of these vectors in conjunction with belt tracking measurements, results in longitudinal belt tensions at discrete intervals across the belt. Information obtained from this method may assist in the determination of splice integrity, structural misalignment and belt manufacturing anomalies.

2. INTRODUCTION

There often arises the need to determine the variation in the belt tension across a belt for the purposes of correctly diagnosing certain belt faults. For example this method has been used on a 2m wide declined conveyor carrying copper ore which was experiencing extreme lagging wear on one third of the drive pulley, and a 1.8m inclined belt carrying coal exhibiting excessive belt tracking deviations.

Longitudinally, the tension within a belt varies according to its location along the conveyor and the operating status of the belt, i.e. empty, full, starting, stopping, etc. The general assumption in a conveyor system is that the belt tension is constant across each transverse section of belting, though it is possible that the tension distribution may be of a random form, as shown in Figure 1, due to variables within the belt construction and structure alignment. This average tension is quoted as a distributed tension with units of force per unit of width or as a total tension with units of force. This paper presents a method of obtaining the belt tension distribution across the conveyor belt under operating conditions.

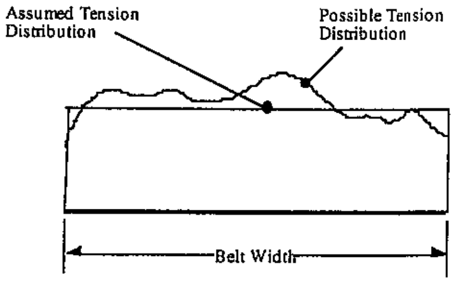

Figure 1: Possible Tension Distribution

3. MEASUREMENT TECHNIQUE

The technique presented in this paper employs the use of a force vector displacement method to determine the tension distribution. The force vector displacement method involves the measurement of the force required to displace the belt a given distance from the datum line of the belt. Together with the geometry of the set-up, as shown in Figure 2, it is possible to determine the belt tension at that location.

The method uses three standard idlers mounted on six load beams, as shown in Figure 3, two belt tracking monitors, an infrared belt revolution indicator, and a belt speed sensor. By inducing a predetermined deflection of the belt with the idlers, it is possible to obtain an approximation to the belt tension distribution across the belt, as shown in Figure 4.

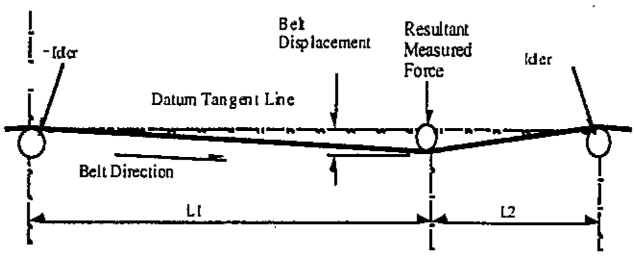

Figure 2: Geometry of the Force Displacement Method

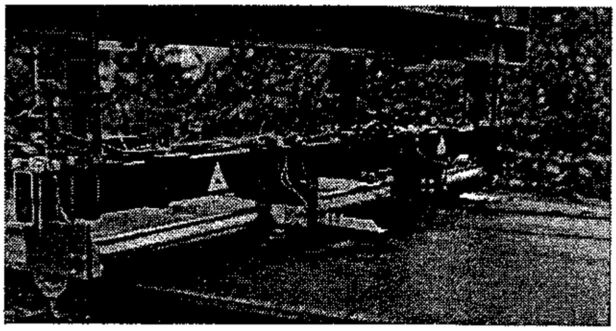

Figure 3: General Set-up of Apparatus

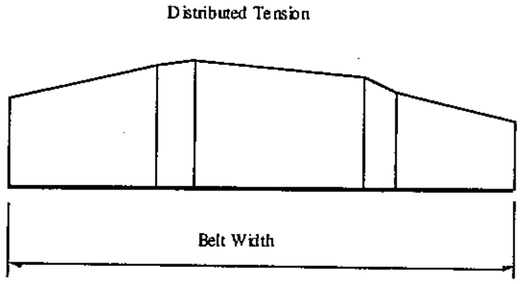

Figure 4: Approximation of Distributed Tension

The total resultant force used to obtain the induced deflection is the sum of the measured force plus the idler weight and an equivalent weight of belt. For small values of displacement, Equation 1 allows the belt tension T to be calculated if values for the measured force F, the total displacement δ, the belt weight W, the idler weight I and lengths L1 and L2 are known.

$$T = \frac{F+W+I}{\delta\left(\frac{1}{L1}\right)+\left(\frac{1}{L2}\right)} \qquad \text{Equation 1}$$

A calibration check can be conducted by displacing the belt, while stationary, in discrete steps and force measurements taken until the required maximum deflection is reached. To determine the initial sag deflection, and thus the total deflection, the force displacement relationship can be assumed to be of the form shown in Figure 5 by assuming the belt tension remains constant during this calibration check.

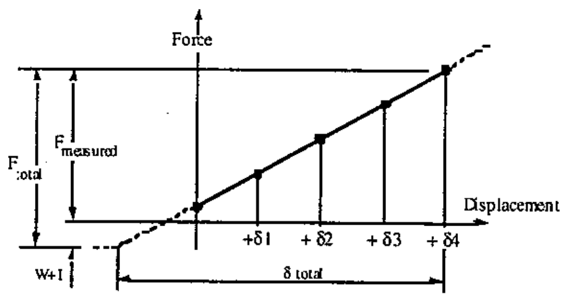

Figure 5: Assumed Force Deflection Relationship for Calibration

To measure the distributed belt tension using the force vector displacement method, it is necessary that the belt be displaced at a location between two support points for the belt - in most cases between two existing idler sets. Experience has shown best results are obtained when the measurements are taken at a location where the belt is flat.

The distributed tension has values defined as WLL at the left hand edge of the belt, WLR at the joint between centre and left hand idler, WCL at a distance of one sixth the belt width to the left of the centre line of the structure, WCR at a distance of one sixth the belt width to the right of the centre line of the structure, WRL at the joint between centre and right hand idler, and WRR at the right hand edge of the belt.

The arrangement of idlers and load cells is shown in Figure 6. The output of the load cells, the two tracking monitors and a belt revolution indicator are recorded at suitable time intervals, typically 1-5 seconds, for later analysis.

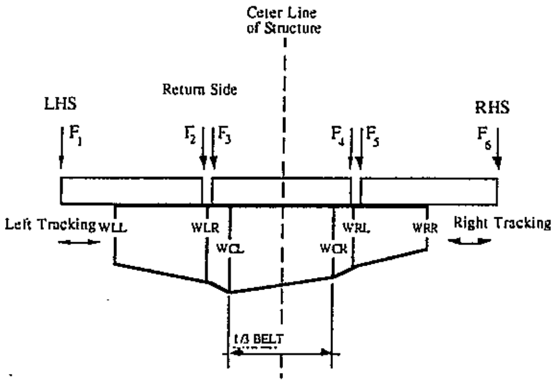

Figure 6: Arrangement of Idlers, Belt, and Measured Forces

An infrared sensor is used to detect a white paint mark on the belt to indicate the belt undergoing one complete revolution. The use of a video camera to determine the position of each splice relative to the white paint mark, enables the recorded data to be cross referenced to a position on the belt length. The time stamp on the video recording can be used to correlate the passing of each splice in the acquired data.

A belt speed sensor may also be used to enable distance travelled by the belt to be calculated. This can be useful during starting and stopping when the belt is not travelling at a constant velocity to determine splice locations in the data.

Figure 3 shows the general set-up of the apparatus including the infrared belt revolution indicator on a 1.8 metre wide belt.

Figure 7 shows one of the belt tracking monitors. The tracking monitors enable the width of belt in contact with each idler to be calculated. Two tracking monitors are used to determine any deviation in overall belt width.

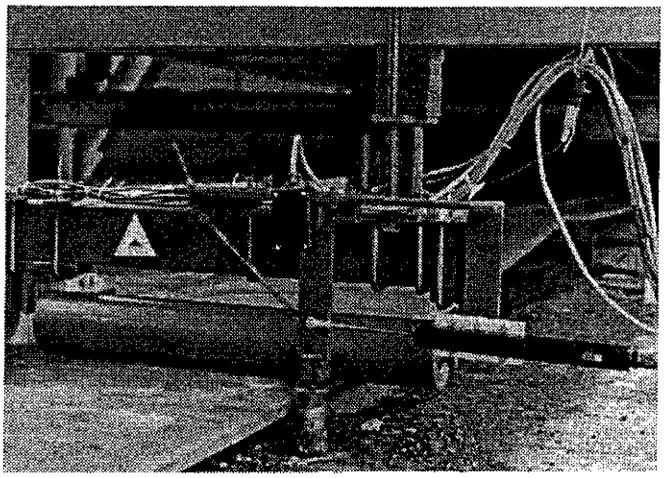

Figure 7: Belt Tracking Monitor

By measuring the forces at the locations shown in Figure 6, after displacement by δ, and knowing the general geometry of the system plus the length of belt in contact with the idlers at any instant, WLL, WLR, WCL, WCR, WRL, and WRR can be computed from a force and moment balance assuming the section of belt between the idlers acts as a hinge. Thus measurement of the force vector by load cells 1 through 6 plus measurement of the tracking displacement is sufficient to determine the tension distribution across the belt.

4. PRESENTATION OF THE OBTAINED DATA

The data presented in this paper was obtained from a 1.8 metre wide incline conveyor used to transport coal. The apparatus was set-up in the loop take up region of the conveyor between two flat reurn idlers.

This procedure provides the following information concerning the conveyor belt:-

- Belt tracking data. A direct output of the location of each edge of the belt with respect to the structure. Figure 9 shows left and right edge tracking versus time. The need to measure the tracking on both edges is due to the possibility of non constant belt width.
- Any trends in belt tension distribution can be obtained, by plotting each tension component with splice locations and tracking versus time. Figure 10 shows left edge tension, left tracking, and splice positions versus time.
- A three dimensional belt tension diagram can be produced using a surface modeling package. This allows the entire belt length to be investigated using a single diagram to determine if any

particular part of the belt requires further in depth analysis. Figure 8 shows an example of an isometric view of the tension distribution over a section of a conveyor belt. The deviation in the belt tension distribution at Splice B (occurring for approximately 100m of belt) suggested further investigation of the data around this splice location is required.

- Individual splices can be investigated. By plotting the tension distribution before and after a splice, any effect of the splice on the tension distribution can be seen. Figure 11 shows a splice with little effect on the belt tension distribution and Figure 12 shows a splice having a noticeable effect on the belt tension distribution.

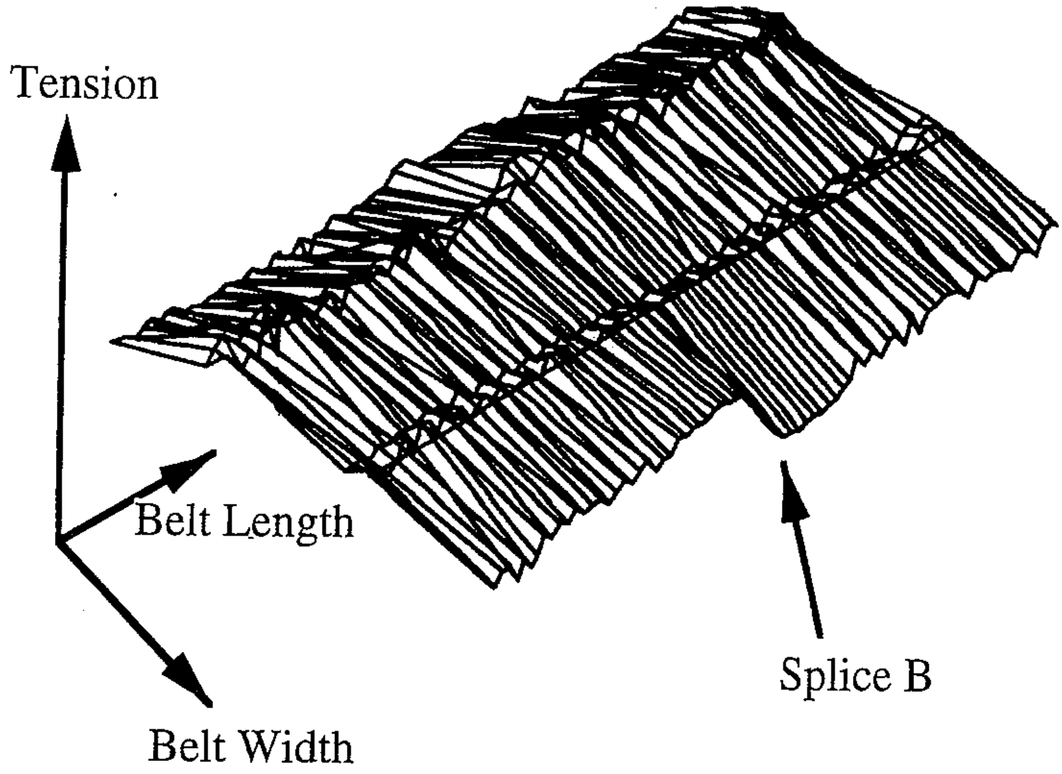

Figure 8: 3D Isometric Tension Diagram of a Section of the Belt

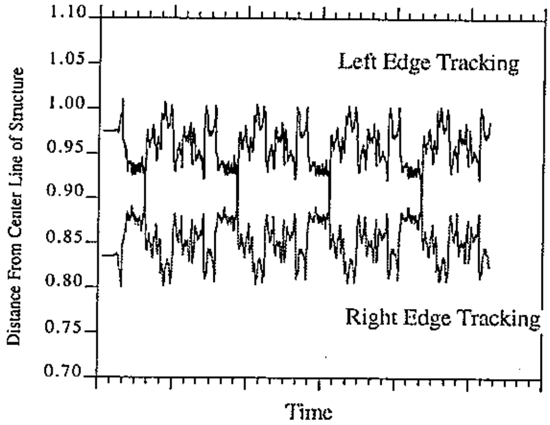

Figure 9: Belt Tracking Vs Time

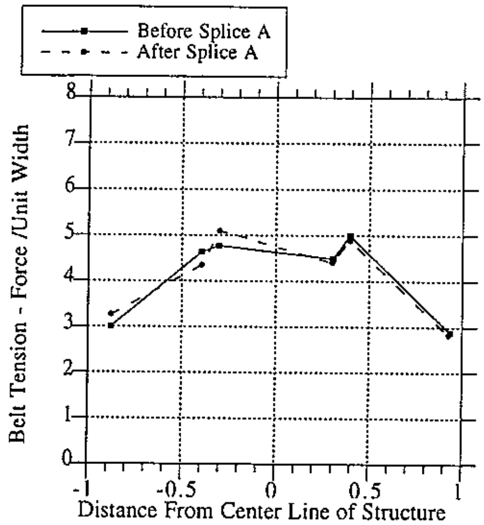

Figure 11: Tension Distribution Before and After Splice A

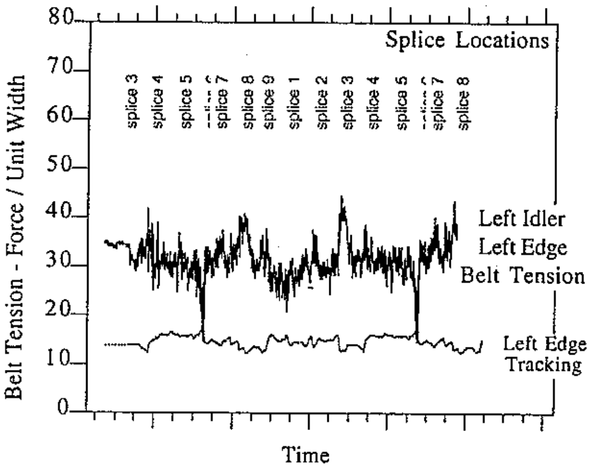

Figure 10: Left Edge Tension, Left Tracking, and Splice Positions Vs Time

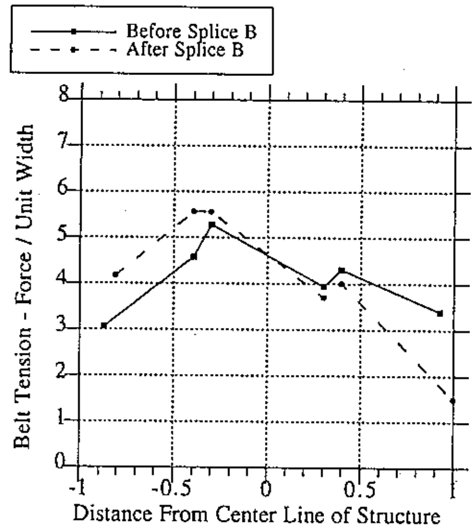

Figure 12: Tension Distribution Before and After Splice B

- If required the total belt tension can be obtained, this may be useful as a further check or to investigate possible causes of problems, such as counterweight jamming etc. Figure 13 shows the total belt tension, splice locations, and left edge belt tracking.

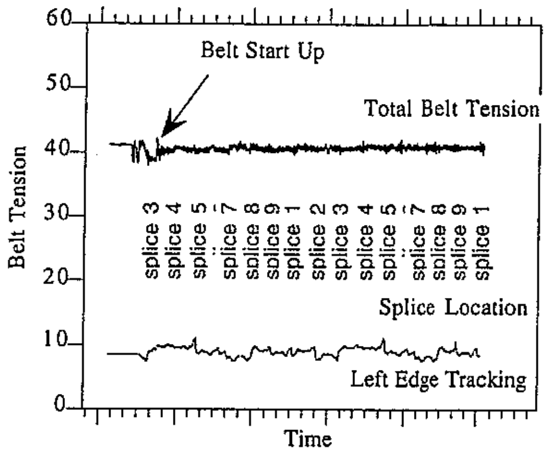

Figure 13: Total Belt Tension, Splice Locations, and Left Edge Tracking Versus Time

5. CONCLUSIONS

This paper briefly describes a technique for the determination of the belt tension distribution across the belt during the operation of a conveyor belt. Examples of the type of information obtained by the technique are presented in graphical form.

The technique may be used to evaluate an existing conveyor belt for splice integrity, structural misalignment, and belt manufacturing anomalies.

At present the analysis involves a rather lengthy process using various computing software. It is hoped this process can be streamlined in the future to reduce number of processes involved in the analysis.

References

1. Madden WF & Scott OJ "Measurement of the Belt Tension Distribution on an Operating Conveyor Belt" 5th International Conference on Bulk Materials Storage, Handling and Transportation. Newcastle NSW Australia, July 1995

6. ACKNOWLEDGMENTS

The author wish to acknowledge the assistance given by:-

The Institute for Bulk Materials Handling Research, for supporting this project.

TUNRA Bulk Solids Research Associates for the use of equipment and technical staff.

Prof. A.W. Roberts for his continuing support in all areas of bulk materials research.