TECHNICAL INNOVATION'S EXTEND LIFE OF PALABORA'S MAIN SLOPE BELT

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ABSTRACT:

Hard rock conveyor belt life cycle cost is set by the belt's cover wear life. Little is published that identifies means of increasing belt life by reducing the belt cover attrition mechanisms. This paper presents an overview of the procedures used to improve Palabora's main slope conveyor belt cover attrition through reducing ore turbulence in the loading zone. Two procedures were executed. First, ore flow stream turbulence was quantified with a mathematical model that determined velocity and pressure gradients in contact between ore and chute, and ore and belt. It followed that the chute could minimise damaging velocity and pressure gradients. A curved chute profile is presented which meets these objectives. Second, ore flow stream turbulence was reduced by providing consistent flow to the slope belt from the primary crusher feeder. A superior belt feeder / crusher pocket speed algorithm was developed. The feeder speed is anticipated by looking ahead at truck arrival time and payload, and by integrating this with the crusher pocket ore level. These key points are presented now as a case history, after nineteen months of successful service.

INTRODUCTION

Palabora Mining Company conveys copper ore up a 15.5 degree sloped tunnel conveyor from the in-pit gyratory crusher to the mill feed stockpile. The primary crusher has a -200 OSS. The design flow rate is 6500 t/h, with a 4 m/s belt speed. Large lumps up to 60 kg (+600 mm) impact the 1800 mm wide belt in the loading zone. The steel cord belt is rated at ST-6600 N/mm and has an 18 mm top cover, 9 mm bottom cover, and 12.4 mm cable diameter with a top and bottom breaker fabric. The cover has a DIN-X wear rating (abrasion value < 100 mm3). Material was fed from the crusher reclaim feeder belt on to the incline belt through a standard design rock box as illustrated in Figure 1.

FIGURE 1: TYPICAL HARD ROCK BOX

It took five years to cut, gouge, and scrape the 18 mm belt cover down to the steel cord surface. It takes approximately 9 million Rand (2.5 million USD) to replace the belt including 1R/ton haulage cost penalty during downtime. Palabora sought to reduce this large replacement cost. The original belt conveyed 114.4 million tonnes. Conveyor Dynamics, Inc. (CDI) accepted a request from Palabora to study possible cost improvements using a curved chute as one alternative.

Palabora's experiment with their curved transfer chute is chronicled in a paper by the author published in 1994 in Bulk Solids Handling [1]. This presentation provides an overview of that paper and expands on it through practical operator commentary on the mine's role in a) deciding to make use of the concept, and b) on-going monitoring of belt wear and chute liner wear to provide long term projections on their cost significance along with other benefits.

Poorly spaced truck arrivals, at the crusher, caused interruption of the ore feed onto the incline belt. The belt feeder speed was linearly regulated to the crusher surge pocket level. A low pocket level shut down the feed. High rock turbulence, spillage, and impact idler damage arose when the truck fleet size dropped and truck arrivals became more staggered causing more frequent flow stoppage. Palabora requested that the belt feeder speed algorithm be evaluated to minimise the damaging turbulence caused by the flow interruptions. The primary crusher belt feeder speed algorithm was improved with the aid of Monte Carlo simulation. A simulation technique is presented. The technique uses a truck dispatch algorithm to optimize the truck flow between crusher and shovels. A simple counting of feeder shutdowns per shift determined the best algorithm. Actual field data was used to validate the model. The simulation demonstrates an opportunity to increase crushing performance, resulting in improved mill grinding throughput.

THE PROBLEM

Figure 2 shows a cross-sectional photograph of the top belt. The belt is beginning to axially split into two pieces at its center. Practically, the belt should have been replaced six months sooner. The belt was nursed along to coincide its replacement with the scheduled crusher liner maintenance.

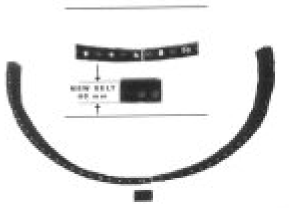

FIGURE 2: WORN BELT CROSS SECTION

CURVED CHUTE MODEL

Figure 3 shows a schematic of the model concept. The model is derived from "open-channel" or free surface flow principles. The material flow is characterised using volume meshing with a look ahead scheme that builds the flow field incrementally starting from the feeder discharge. A finite difference mathematical model is used. The mesh 3-D elements are mathematically formulated with surface drag between elements using hydrostatic pressure, flow stream pressure, and simple drag coefficients between material elements, and between material and chute surfaces. Material internal slip angles (surcharge) and material free fall are accounted for. The ore friction coefficient with the chute liner was modeled using a simple rock sliding on an incline plane scheme.

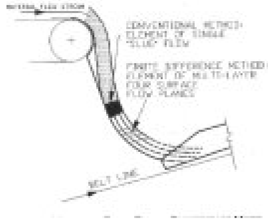

FIGURE 3: MATERIAL FLOW FINITE-DIFFERENCE MESH

Many curvature forms were studied including: linear (conventional rock box), parabolic (circular) and higher order polynomial shapes. Illustrated in Figure 4a, b. Figure 4 also shows the calculated ore flow velocity. We found that the circular shape to provide best overall result. The chute design had to minimise both belt cover and chute liner attrition. The initial chute contact surface was selected to intercept the ore flow stream at approximately a 15 degree impact angle. The chute is not curved until more than a third of the ore stream is bedded on the chute liner at the low impact angle. The curve then followed a circular arc, bending the flow into the falling ore stream. The arc continues until the exiting ore stream provides the minimum ore Pressure-sliding Velocity Gradient product (PVG) with the belt.

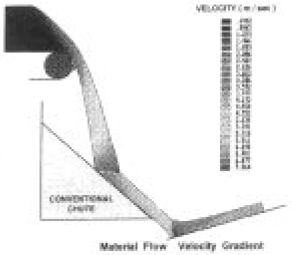

FIGURE 4A: ORE VELOCITY IN ROCK BOX

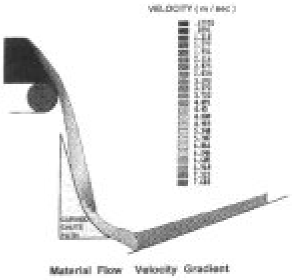

FIGURE 4B: ORE VELOCITY IN CURVED CHUTE

DAMAGE MECHANISMS

Figures 5, 6 and 7 illustrate the model results for the ore-belt sliding-velocity along the skirt zone, the flow stream pressure, and their PVG product. Figure 8 is a diagram of the proposed chute. The belt abrasive damage factor is estimated to be in proportion to the PVG value. The curved chute provides less than half the abrasive index of the rock box. The gouging damage is more difficult to estimate. If the rock impact pressure cannot force the rock edge to penetrate the rubber with a force that exceeds the rubber yield stress at impact, we theorise the rubber will not tear. Gouging damage will be eliminated. We theorized that the main damage mechanism was gouging as identified by field investigation. The belt surface is heavily pitted. Figure 9 illustrates a typical relationship between gouging and abrasion observed by field monitoring of wear. Note, the operator observes only abrasive loss of belt cover until the surface pitting damage coalesces. Surface pitting is caused by larger rocks with sharp edges. Pitting or gouging is initially observed as local small divots, or scars, that will not be recorded by a simple straight edge measurement technique, The analogy is made to rain drops. individual drops can be seen falling on a dry surface, until the drops cover the surface and coalesce (become one). After coalescence, the damage becomes obvious. The belt is more easily damaged by the same rock impact for two reasons: 1) lighter pressure and smaller rocks can initiate surface tearing; 2) rubber's polymer molecular surface resilience has been destroyed.

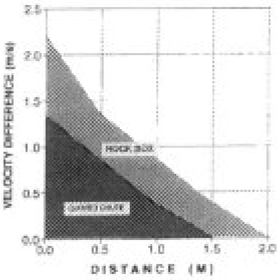

FIGURE 5: SLIDING VELOCITY ON BELT @ IMPACT

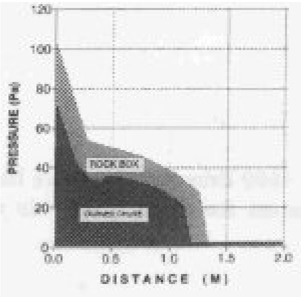

FIGURE 6: PRESSURE ON BELT @ IMPACT

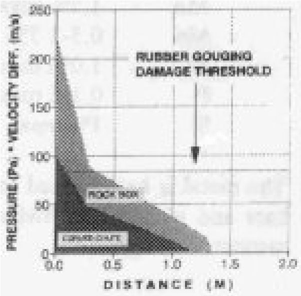

FIGURE 7: PVG PRODUCT @ IMPACT

CURVED CHUTE CONSTRUCTION

The chute curvature follows a two meter radius subtending a 55 degree are as illustrated in Figure 8. This was found to provide the best PVG factor. The chute side walls are straight and are tapered full length. The bottom surface is flat. A curved or circular shaped bottom was found to increase the hydrostatic pressure and reduce the flow rate.

Palabora proposed the use of their small mill liner material for the chute liner. The material is a high chrome metal casting (BS 4844 Part 3 Grade 3D) with the following chemistry:

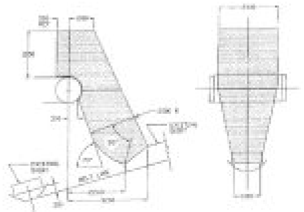

FIGURE 8: CURVED CHUTE DIMENSIONS

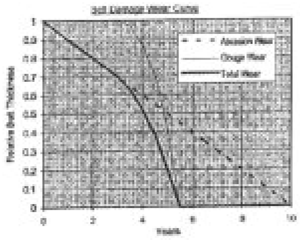

FIGURE 9: BELT WEAR DAMAGE vs TIME

Cr	22-28%
C	2.4-2.8%
Cu	1.2% max
Mo	1.5% max
Mn	0.5-1.5%
Ni	1.0% max
P	0.1% max
Si	1% max

The metal is heat treated to a +600 Brinnel. The curve liner plates are cast into 12"x16"x4" bars and placed lengthwise across the chute. The side walls were also lined in a similar manner.

CHUTE WORKING HISTORY

The chute has been installed for nineteen months. It has passed 36.6 million tonnes. Belt wear measurements were taken recently. To date almost no visible wear (1-2 mm) is detected. Gouging damage seems to have been nearly eliminated. The belt is expected to last the thirteen year length of the open-pit mining operation.

Prior to the curved chute and feeder speed algorithm changes, a typical maintenance shift required a full eight hours to cleanup rocks around the load station, and replace damaged impact rolls. The operating crew worked a six day week. A separate crew cleaned up tunnel spillage, replaced damaged idlers, and washed down material carry back.

Today, the operating crew works a seven day week, with eight hours for maintenance. Now, one crew can wash down the tunnel and replace the damaged rollers. Load station spillage has been nearly eliminated. Impact idlers no longer fail on a weekly basis. The amount of material carry back is noticeably reduced. Idler replacement in the tunnel is also reduced.

Two rows of liner bars need replacement at the impact station about every four months. The two downstream rows, at the discharge, last about six month. The adjacent side panels require six month replacement.

The chute was installed back from of the recommended point by 150 mm. This increases the impact force and liner wear, but does not influence belt damage. The chute will be moved to the correct position in the near future.

COST FACTORS AND SAVINGS

The five year cost trade-offs between the rock box chute and curved chute are:

A. **Original Design**

Belt cost including installation:	R7 900 000	
Haulage cost increase (1 R/ton):	R1 100 000	During down time
Total Belt Replacement Cost:	R9 000 000	
Maintenance:		
Idlers, cleanup	Not Factored	
Liner wear	Not Factored	

B. 114,400,00 tonnes were hauled over five years. Today 29,930,000 tonnes are hauled per year. The equivalent haulage time is 114,400,00 / 29,930,000 = 3.82 years.

C. Therefore, Net Present Value (NPV) cost per ton @ 8% interest is:

D. Total Cost (R/t) = R9 000 000/29 930 000 x3.82 years/$(1.08)^{3.82}$
= 0.0586

E. **Curved Chute Design**

Chute fabrication:	Not Factored
Maintenance, except liners:	Not Factored
Belt Replacement NPV @ 8%, 13 years	= 0.00851 R/t
Line replacement:	R116.00/29 930 000 t
	= 0.00359 R/t

Total Cost R/t = 0.0124

F. **Cost Difference Per Year**

29 930 000 t(0.0586 R/t - 0.01242 R/t)
= R1 389 000

G. **Cost Savings for Mine Life in NPV Terms**

R1 383 000 x 7.9 (13 years @ 8%)
= R10 924 000 (2 993 000 USD)

The curved chute is predicted to reduce the risk of belt ripping from shovel teeth, drill bits, etc. The ore flow stream is intercepted by the chute, eliminating a direct drop to the receiving belt.

MONTE CARLO SIMULATION - IMPROVED BELT FEEDER SPEED ALGORITHM

Modular Mining's truck dispatch algorithm is used by Palabora. The algorithm controls all tracks in the pit. This dispatch algorithm was used in our evaluation of truck arrivals to the crusher. Actual field records were also used to provide accurate data on the initial operation.

Production sensitivities including: truck allocation, haulage variables, crushing rates, and crusher surge pocket variations were studied. Four shovels were distributed in the pit at different distances from the crusher. All traffic flow restrictions were included.

Improvement in ore flow onto the incline conveyor can be obtained by using the future arrival information on the trucks as they approach the crusher.

We used a General Purpose Simulation Language developed by Wolverine Software (U.S.A.). Probability distribution functions were developed for the shovels, trucks, truck dump traffic, and crusher.

Several competing feeder speed control algorithms were simulated. The idea is to keep the belt feeder running as long as possible at or above the allowable minimum speed (ore flow rate), keeping the crusher pocket above the minimum level, without holding up trucks dumping to the crusher. Belt feeder acceleration and deceleration become important factors in the algorithm strategy.

The truck rout dispatch algorithm defines the estimate of the truck arrival time, and the crusher PLC estimates the ore pocket level. The feeder speed is based on these estimates.

Results of the simulation show significant improvement is possible. The following table shows the improvement.

Number of Trucks	Pocket = 420 t Crushing Rate	Shutdowns/Shift Existing Algorithm	Shutdowns/Shift Improved Algorithm
6	5000	30.4	0.2

10	5000	1.6	0
12	5000	0.1	0
6	6000	38.2	0.4
10	6000	6.3	0
12	6000	1.0	0

	Pocket = 280 t	**Shutdowns/Shift**	**Shutdowns/Shift**
Number of Trucks	**Crushing Rate**	**Existing Algorithm**	**Improved Algorithm**
6	6000	51.8	1.1
10	6000	17.8	0
12	6000	5.1	0

With light and moderate truck fleet sizes, the speed control algorithm can provide significant direct benefit. A potential side benefit is to use the longer times between truck arrivals to lower the crusher OSS (with the hydroset) to provide a smaller product to the mill.

CONCLUSION

Palabora has realised significant improvements in belt wear attrition, and in plant maintenance associated with spillage and idler replacement. They indicate the curved chute benefits warrant converting other troublesome transfers to this concept. Monitoring will continue and its progress will be reported to the industry.

REFERENCE

Nordell, L.K., "Palabora Installs Curved Transfer Chute in Hard Rock to Minimize Belt Cover Wear" Bulk Solids Handling, Trans Tech Publications, Vol. 14, No. 4, 1994.