SPECIALISED BELT HANDLING EQUIPMENT FOR INCLINE BELT CONVEYORS

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Abstract

Historically incline shaft conveyors were being operated as dual conveyor systems to minimise the risk of mine stoppage in the event of downtime associated with the maintenance on these conveyors. Cost considerations are dictating that single conveyors be used in place of the dual conveyor systems.

The current approach is to install a single conveyor only. To this end special attention is required for ensuring that the downtime is still minimised for maintaining and replacing the belting used on this conveyor.

This paper intends to outline the minimum requirements that needs to be put in place to mitigate the situation. The discussion will be focussing on the storage requirements of the belting, the physical handling of the belting and the installation of auxiliary equipment required for the belt handling process. Specific subject matter that will be discussed will include belt reeling units, belt pulling units and belt clamping systems.

All this subject matter may possibly be daunting to some hence the presentation is structured along the following lines:

1 Provide an **overview** of all the actions required on the belting.

2 **Discuss** each of these actions as listed.

3 Set up an **example** to illustrate all the matters discussed.

4 **Work** through and execute this **example** in some detail for discussing salient points.

5 Derive and make a list of all the **concluding** issues.

6 Make **recommendations** on the way forward.

1. OVERVIEW

On any conveyor system there are specific actions that need to be addressed holistically to facilitate the successful operation of a belt conveying system. To this end the following is considered as being a comprehensive list of these actions:

1.1. First time installation of the belting on the structure.

1.2. Maintaining of the belting during production.

1.3. Replacing a section of damaged belting during operation.

1.4. Retrieving of a broken belt.

1.5. Agreed storage requirements for validating warranties over an extended period usually much longer than the normal factory guarantee period.

1.6. Replacing the entire conveyor belt once it has reached the end of its useful life and is worn out.

2. DISCUSSION

2.1 First time installation of the belting on the structure.

2.1.1 It is normally a project requirement that the belting be installed as a pre-spliced full-length unit. On a 1000m terminal pulley centre distance at least a 2000m plus length of belting will be required. This length will typically be built up from 300m rolls of belting supplied from the conveyor belting factory. Effectively a minimum of seven rolls of belting will thus be required. Similarly belt splices will be required for joining and installing the seven lengths of belting.

2.1.2 After splicing the full length of belting can either be stored on a purposed designed belt reel or reeved and put on the ground.

Figure 1 - Belt reeler for storing the belting

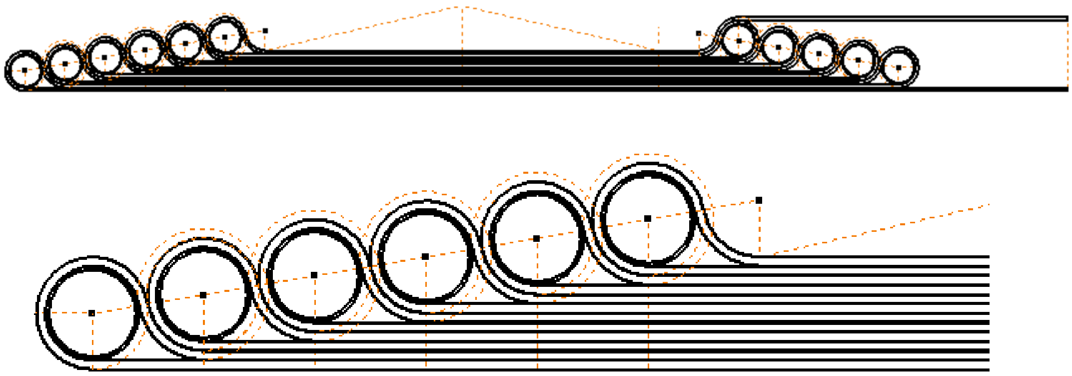

Figure 2 - Reeved arrangement for storing the belting

2.1.3 The next step will be to pull the belting on the finished conveyor structure. A procedure will be drafted describing the process and the equipment required to complete this process. The procedure described in this presentation is considered a practical method of doing it but it must be noted that there are certainly other ways of doing it as well. This method is considered as being practical for discussing the majority issues that will be encountered.

2.1.4 The equipment normally used to this end will be:

- A D9 bull dozer or a belt pulling winch.
- Purpose designed clamping goods for attaching the steel wire rope to the free end of the conveyor belting.
- Functional belt clamps strategically placed along the installation.
- Additional safety belt clamps placed along the installation.
- Additional pulleys strategically pulleys placed along the length of the conveyor for bending and deflecting the belting as and where required.
- Steel wire rope sheaves strategically placed along the length of the conveyor.
- Splicing station(s) strategically located for executing the belt splicing operations.

2.2 Maintaining the belting during production.

2.2.1 This maintenance is seen as being the small actions required like repairing damage to the covers of the belting and also removing blisters which may have developed. Shorter cuts and holes will also be vulcanised or mechanically clipped. In essence these are localised repairs required to be executed on the conveyor belt.

2.2.2 The timing for executing these actions will typically be during either routine weekend shutdowns or planned periods of extended maintenance.

2.2.3 When conducting this type of maintenance to a conveyor, it is not necessary for the belting to be cut. Due to this, these repairs can readily be undertaken in the high tension areas upon engagement of the high tension fixed belt clamps. Repairing small slits along the length of the belt it will also be in order as it can be done in either the high or low tension areas of the conveyor.

2.2.4 When a belt joint needs to be respliced, please refer to the latter section of this document before making a final decision as to where this should be done.

2.3 Replacing a section of damaged belting during operation.

2.3.1 In this instance a section of the belting would have been damaged during operations. The requirement is that say from a short 20m length up to 300m length of belting needs to be cut out from the main belt and replaced.

2.3.2 The required length of the belting may be taken from the belt storage unit for purposes of splicing it into the system. To this end the storage length of the complete belt should not be compromised for replacement of a full length of belting under short notice at any point in time.

2.4 Retrieving a broken belt.

2.4.1 There is always the possibility that the belt may snap during operation. That is the reason why most operators conduct ongoing condition monitoring of the installation in order to prevent this from happening.

2.4.2 Be that what it may, contingency planning needs to be in place to deal with this in the unlikely event that it does happen. The options are the D9 dozer, belt pulling winch or a powered reeler.

The D9 dozer will have a steel wire rope attached to the drawbar and the other end to the broken belting in the shaft.

The belt pulling winch can be used for this application as well. The D9 dozer may not always be readily available making the winch an ideal solution.

In the event of a powered reeler being available it can be used to do the same. The free end of the belting on the reeler can be lowered down the shaft, attached or spliced to the broken end of the belting and pulled back up the shaft.

The key to making any of the aforesaid work is to ensure that there is provision for adding belting to the system.

2.4.3 The belt retrieval system will not be discussed any further as the above notes are considered to be adequate. All the other details and intricacies involved in this process will be covered in the other detailed discussions later on in the presentation.

2.5 Agreed storage requirements for validating warranties over an extended period usually much longer than the normal factory guarantee period.

2.5.1 The average warranty on a conveyor belt range probably from a year to say three years. If one has a spare conveyor belt available for purposes of replacing the existing belt at very short notice in order to keep mining going, it becomes a problem. In stating the obvious, the life expectancy of the existing belt will be a certain number of years which is definitely longer than the standard warranty on a conveyor belt. After the belting is replaced, the newly installed, but old and aged belting, is then expected to run for the similar period of time for which the original belting operated. In all probability this replaced belting may even be carrying more product than the belting being replaced.

2.5.2 A specific arrangement is required between the user and the supplier with reference to the guarantee period. From experience in the past, the supplier will consider this but will impose specific requirements for honouring the agreed guarantee.

2.5.3 One of the specific requirements is that the long-term stored belting must be rotated every so many months.

2.5.4 If the belting is stored on a purpose designed vertical belt reeler, the reeler must be turned and the belting rotated through say 90 degrees every three months or so as per the supplier's requirements.

2.5.5 The requirement for belting stored on a horizontal reeler is that the belting needs to be turned upside down every 12 months. Unless one has two horizontal reelers, the logistics in this instance are problematic.

2.5.6 Ever wondered why the outside of a kreel is not round? Now you know. Even storing a standard reel of belting in the mine store, it has to be rotated accordingly as well.

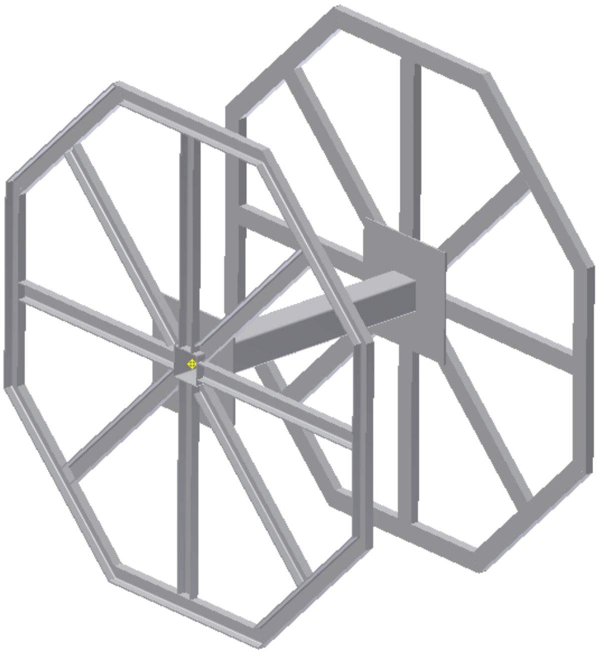

Figure 3 - Octagon shape of a belt kreel

2.5.7 The other main requirement is that it may not be stored in direct sunlight. The uv rays of the sun negatively impacts on the rubber of the conveyor belting. Typically, the purpose designed belt reeler systems are normally under roof to meet this requirement.

2.5.8 The aforesaid describes the essence of the storage requirements for conveyor belting.

2.6 Replacing the entire conveyor belt once it has reached the end of its useful life and is worn out.

2.6.1 The free end of the belting on the reeler is unwound and attached to the existing conveyor belt. This is achieved by either making use of bolts or a standard splice.

2.6.2 The old conveyor belt is then cut and the free end pulled out underneath the reeler and attached to a pulling device. This device can either be the D9 bull dozer or the belt pulling winch.

2.6.3 As the new belting is now being pulled off the reeler and into the conveyor, the old belting is slowly being pulled out of the installation on surface.

2.6.4 The process continues until all the old belting is pulled out of the conveyor and all the new belting is placed in the system.

2.6.5 At this point the end of the old belting is detached from the new belting. The ends of the newly installed belting are now joined and the belt is ready to be placed back in service.

2.6.6 The forces present in this system will become clearer once the example is worked for quantifying these forces.

3. EXAMPLE

3.1 Basic Conveyor profile

For this example the conveyor will be considered to have a flat section of about 140m at the tail. The conveyor needs to have a vertical curve to take it up the 15 degree incline where it will discharge into a silo on surface.

The horizontal pulley centres will be 1000m and the vertical lift 230m. The discharge height into the silo is 30m above ground level.

The system will be fitted with a tail take-up and the drives will be situated on surface on the return side on surface. It will be a dual drive arrangement with two power units on the primary drive pulley and one drive on the secondary pulley.

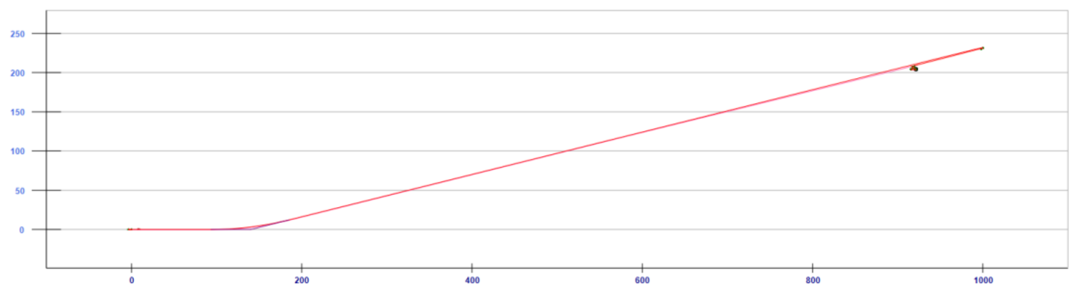

Figure 4 - Overall conveyor profile

Figure 5 - Tail section of the conveyor

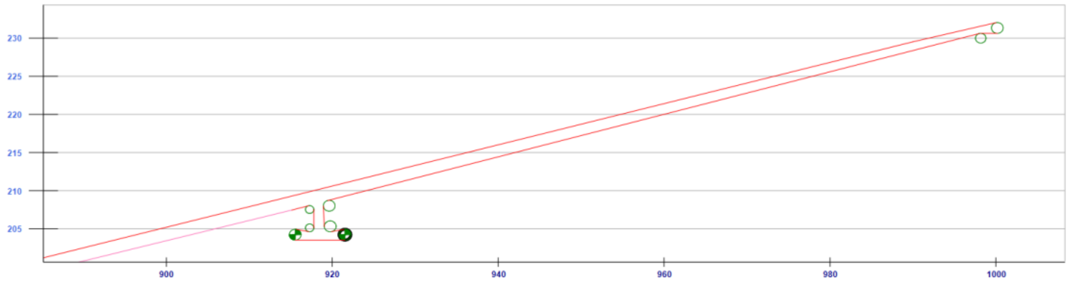

Figure 6 - Head section of the conveyor

Belt width assumed as being 1350 wide.
Belt capacity assumed at 2500 tons per hour.
Three roller 152mm diameter series 30 idlers used to SANS 1313 and troughed at 35 degrees.
Vee return 152 diameter series 30 rollers used to SANS 1313 and troughed at 10 degrees.
Terminal pulley centres set at 1000m.
Friction factor used for this design 0,022.

3.1.2 The following values were calculated:

- Belt class: ST - 3150
- Belt mass: 55.1 kg/m
- Belt length: 2092 m
- Friction factor: 0,022
- Number of troughing idlers at 1500mm pitch = 683 with an equivalent rotating force of 111N.
- Number of vee return idlers at 4500mm pitch = 226 with an equivalent rotating force of 100N.
- There are 10 pulleys in the system. The pulleys are listed below in sequence starting at the head pulley and working one's way down to the tail take-up pulley. Each of the individual pulley masses are listed and noted accordingly.

Pulley description	Mass per unit	Unit of measure	Rotating force	
Head Pulley:	5957	kg	1285	N
Pulley 2:	2560	kg	552	N
Pulley 3:	5124	kg	1105	N
Pulley 4:	5124	kg	1105	N
Motors 1/2 - Backstop 1:	5939	kg	1281	N
Motor 3 - Backstop 2:	5939	kg	1281	N
Pulley 7:	2476	kg	534	N
Pulley 8:	2476	kg	534	N
Take-up Pulley:	2476	kg	534	N
Tail snub Pulley:	873	kg	188	N

Table 1 - List of pulleys in the system

Material	
Tonnage (t/h)	0
% Area (DIN)	---
Edge Dist (mm)	---
Mat. Mass (kg/m)	---

Motors	
Nameplate (kW)	3 x 900
Reduced MNP (kW)	3 x 734
Demand (kW)	228 / 2201
Percent Nameplate	10.3 %

Take-up		60 000
Req'd (Running)	Sag	TR
Steady State	16 361	-93 178
Dynamic	11 610	-90 454

Idlers	6306	6306	
Min L10 Life	166 363	350 000	
Max Shaft Def.	2.2 / 4.7	4.23	
Diameter (mm)	152	152	
Speed (rpm)	553	553	
Avg Set Drag (N)	---	---	
Avg Spacing (m)	1.50	4.50	
Req'd Pulley Diam	1400	1250	1000

Belt	
Type	Steel
Width (mm)	1350
Speed (m/s)	4.40 / 5.32
Rating (N/mm)	ST-3150
Covers (mm)	8.0 x 8.0
Mass (kg/m)	55.1

General	
Temperature (°C)	10.0
Length / Height (m)	1 000 / 230
Material Lift (m)	0.0
Belt Line Mass (kg)	203 976
Din Factor f / Cs	0.0220 / 1.305
Curves / Flap	Ok / Ok

Tensions	Max (kN)	SF	Splice SF	Min (kN)	Sag (%)
Running	203.7	20.88	---	58.8	0.52
Starting	208.2	20.42	---	58.5	0.52
O-Stop	186.5	22.81	---	62.1	0.49
E-Stop	186.5	22.81	---	62.1	0.49

Dynamics	Time	Mtr/Brk	TR (%)
Running	---	10.3 %	M1 - 34
Starting	75.0	12.6 %	M1 - 26
O-Stop	17.6	---	---
E-Stop	17.6	---	

Table 2 - Design showing Empty belt condition

Material	
Tonnage (t/h)	2 500
% Area (DIN)	82 %
Edge Dist (mm)	142
Mat. Mass (kg/m)	157.8

Motors	
Nameplate (kW)	3 x 900
Reduced MNP (kW)	3 x 734
Demand (kW)	2013 / 2201
Percent Nameplate	91.5 %

Take-up		60 000
Req'd (Running)	Sag	TR
Steady State	**16 360**	-36 125
Dynamic	11 610	-51 546

Belt	
Type	Steel
Width (mm)	1350
Speed (m/s)	4.40 / 5.32
Rating (N/mm)	ST-3150
Covers (mm)	8.0 x 8.0
Mass (kg/m)	55.1

General	
Temperature (°C)	10.0
Length / Height (m)	1 000 / 230
Material Lift (m)	230.4
Belt Line Mass (kg)	365 313
Din Factor f / Cs	0.0220 / 1.285
Curves / Flap	Ok / Ok

Idlers		6306	6306
Min L10 Life		166 363	350 000
Max Shaft Def.		2.2 / 4.7	4.23
Diameter (mm)		152	152
Speed (rpm)		553	553
Avg Set Drag (N)		---	---
Avg Spacing (m)		1.50	4.50
Req'd Pulley Diam	1400	1250	1000

Tensions	Max (kN)	SF	Splice SF	Min (kN)	Sag (%)
Running	599.4	7.09	---	58.8	0.60
Starting	613.4	6.93	---	58.5	0.59
O-Stop	371.6	11.44	---	103.0	0.38
E-Stop	371.6	11.44	---	103.0	0.38

Dynamics	Time	Mtr/Brk	TR (%)
Running	---	91.5 %	M1 - 58
Starting	75.0	94.4 %	M1 - 44
O-Stop	3.6	---	---
E-Stop	3.6	---	

Table 3 - Design showing Loaded belt condition

The belt handling system is not sized and designed in accordance with the requirement for lifting equipment. The Conveyor Manufacturers Association has published a belt clamp standard and this document notes the factor of safety as being 3. It thus makes sense to design all the belt handling equipment accordingly.

One must hasten to add that the actual pulling force does not need to meet this specific requirement at all. Normal engineering factors of safety will apply. A sensible barometer will be to have the main and maximum pulling force in the system set at 150% of the required force.

This is as much for setting up the example.

4. WORKING THE EXAMPLE

4.1 The magnitude of the forces in the system

4.1.1 A full length of belting is available on the purpose designed vertical belt reeler. With the belting being 2092m long the total mass of the belting equates to 115 269 kg and this sets the tone for understanding the magnitude of forces in the system.

4.1.2 Due to all the uncontrollable issues associated with the use of a D9 bulldozer, it was decided to opt for a belt pulling winch in this example.

4.1.3 Quantifying the major forces in the system.

- Moving the belting horizontally:

$$2092\text{m} \times 0{,}022 \times 55{,}1\text{kg/m} \times 9{,}81\text{m/s}^2 = 24{,}9\text{kN}$$

- Lifting the belt 230m:

$$230\text{m} \times 55.1\text{kg/m} \times 9{,}81\text{m/s}^2 = 124{,}3\text{kN}$$

- Rotating the troughing idlers:

  683 troughing idlers with rotating force of 111N = 75,8kN

- Rotating the return idlers:

  226 return idlers with rotating force of 100N = 22,6kN

- Rotating all the pulleys:

  Sum total of 10 pulleys as listed = 8,4kN

- Sum total of all the moving and rotating masses:

  Belting + Trough idler + Return idlers + Pulleys

  24,9 + 75,8 + 22,6 + 8,4 = 131,7kN

4.2 Deciding how to pull the belting into the system

4.2.1 Starting on the troughing side on surface, pull the belting up the incline to the head pulley located on top of the silo. Go around the head pulley, over the snub pulley and pull the belting back down on the return side to ground level. Now feed the belting around the pulleys located at the drive station on surface.

4.2.2 Calculate the force to pull the belting up the incline from the surface to the head pulley:

- Belt slope tension from surface to head pulley situated 30m high

  30m x 55.1kg/m x 9,81m/s^2 = 16,2kN

- Rotating forces and belt moving forces

  43 bases x 111N + 55.1kg/m x 116m x 0,022 x 9,81 = 6,1kN

- Maximum force required local to this area is sum total of previous

  16,2kN + 6,1kN = **22,3kN - Maximum force in this area.**

- At this stage there is no braking force required at the reeler to prevent the belting from running down the shaft.

4.2.3 The next step is to continue with the belting back down on the return strand to the tail end of the conveyor.

- At this stage the belt slope tension on the troughing side will balance out with the similar mass on the return side on surface with the 32m lift.

- When the belting starts going underground the force wanting the belt to run down the shaft start increasing. As soon the belt slope tension exceeds the resistive rotating forces a breaking force needs to be exerted.

- As soon as the increasing belt slope tension going underground start exceeding the rotating forces in the structure above ground one is approaching the point where the return strand will want to freely run down the return strand.

- As an indication, the rotating forces equate to 6,1kN (as calculated above) and the equivalent belt length initiating acceleration can be calculated accordingly.

  Potential energy = mass x gravity x height

  6,1kN = 55,1kg/m x 9.81 m/s^2 x height.

  The equivalent height is 11.3m.

- The gravitational force increases down the incline reaching a maximum where the belting starts going horizontally towards the tail pulley.
- Vertical distance from surface to tail is 200m. The belt slope tension developed is 200m x 55,1kg/m x 9,81m/s^2 = 108,1kN. In this instance one would use this value as being the maximum during a stationary condition. The rotating force only enters the equations once movement is taking place and thus this valued is considered to be safe for the application.
- In this instance the braking force is noted as being 108,1kN.

4.2.4 The final stage is to pull the belting along the 140m length to the tail section, wrap the belting around the tail pulley and then pull it back up the incline on the troughing side. The pulling process continues until the entire belt is up to surface. At this point the belt ends are spliced and joined together in order to complete the process.

- Pulling the belting up the incline, one has to overcome the rotating forces on the troughing side plus the belt slope tension. For calculation purposes the horizontal section towards the tail pulley will need to be included as well. The belt slope tension on the return strand is sufficiently large to overcome any and all of the other and rotating forces and does not need to be factored in.
- The pulling force required to pull the belting on the troughing side up the incline will be the rotating forces present on the horizontal section, the tail and snub pulley forces, moving the belting horizontally and raising the belting 200m.

  Return and trough idlers over 140m. =

  94 trough idlers at 111N + 31 return idlers at 100N = 13,5kN

  Tail and snub pulley rotating forces.

  534N + 188N = 0,7kN

  Trough idlers on the incline over the 200m lift.

  515 trough idlers at 111N = 57,2kN

  Movement of belting in this area as well.

  1170m belting length x 55.1 kg/m x 9,81m/s^2 x 0,022= 13,9kN

  Total pulling force required in this instance is sum total of the previous.

13,5kN + 0,7kN + 57,2kN + 13,9kN = 85,3kN

4.2.5 In summary the following forces are present in the system:

- Initial pulling force of 22,8kN is required on surface. Note that sizing the equipment for the largest pulling force will suffice for this instance.
- Largest occurring braking force of 108,1kN is required to constrain the return strand.
- Largest occurring pulling force of 85,3kN is required for hauling the belt up the incline.

Care must be taken to ensure that the equipment is sized adequately and not grossly oversized. Different factors will thus apply for the pulling force and for the braking force.

- With respect to the braking system and all the componentry used for braking and or pulling, the factor of safety of 3 will be applied.
- However, with respect to the pulling force, this safety factor cannot apply as the magnitude of it may well result in the failure and self destruction of the respective equipment under certain conditions. Rating the pulling force at 120% to 150% of the required value will still be more than adequate for the actual duty requirement.
- For this example, the required braking force is 108,1kN.
- Applying the factor of safety of 3, brakes must be sized to 3 times the value.

  108,1kN x 3 = 324,3kN. The braking system must be sized and rated to this value. This includes all the componentry associated with either the braking and or pulling componentry.

- For this example, the maximum occurring pulling force is 85,3kN
- Applying the service factor of 120% to 150% to this value.

  At 120% = 85,3kN x 120% = 102,4kN

  At 150% = 85,3kN x 150% = 128kN

4.3 Belt pulling winch

Figure 7 - Belt pulling winch

- A standard winch with a pull of 14 ton on the bottom layer and 10 ton on the outer layer will be adequate for the duty.
- The winch will be a free standing unit located on surface at the brow of the shaft.
- The drum of the winch must have a capacity of 1000 meters of steel wire rope.

4.4 Vertical belt reeler

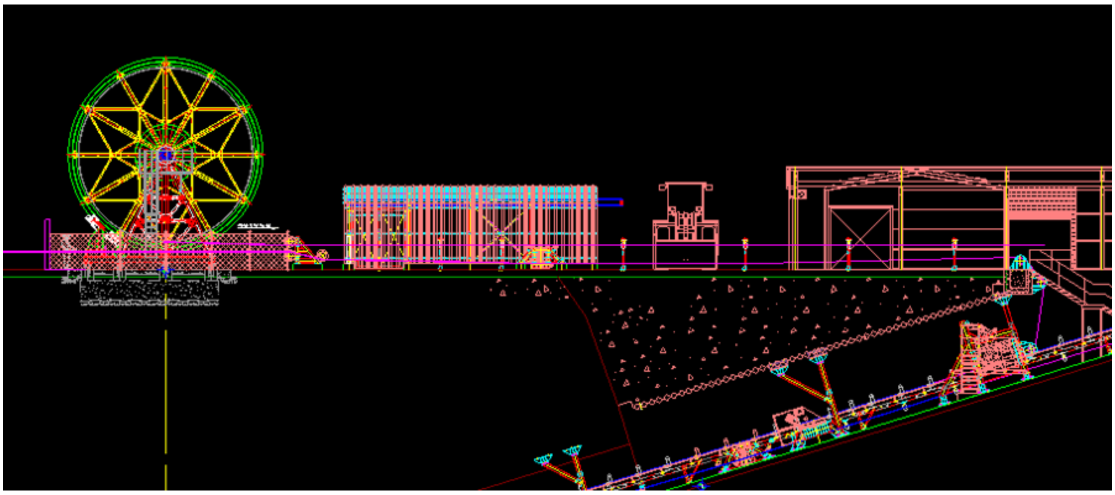

Figure 8 – Typical arrangement of belt reeling facility

- A purpose designed vertical powered belt reeler will be installed for storing and handling the 2092 length of belting. In essence the reel will be 3m over the empty drum and 9m on the outer diameter.
- The reeler will be built-in local to the brow of the shaft and housed in an enclosed building for protecting the belting against harmful uv rays over extended periods of time.
- The power of the reeler will be used to handle and control the 324,3kN braking force in the worst case scenario being the full reel.
- The reeler unit will also be fitted with an independent braking system which will be used for braking and holding the belting in an emergency situation.

4.5 Belt clamp type belt braking system – Alternative option

Figure 9 - Let down belt clamp for lowering the belting down the shaft

- The belting is fed through this the belt clamp. The is used to clamp and hold the belting in place. If the belt is required to move, the clamping pressure is reduced to the point where the belting starts slipping through the clamp.
- This system in essence considered as a manual system and is used throughout the world as being acceptable when used by experienced installers.
- The risk when using this system is the lag time experienced between releasing and then "controlled" braking of the belt slipping through the clamp.
- This option is the alternative to using the powered braking used on the reeler system.

4.6 Attaching the steel wire rope to the free end of the belting

- This is where the duo of Heath Robinson and MacGyver weigh in and enter the equation. As many installations there are as many ways there are to secure the belt pulling rope to the end of the belting.
- Lashing of the belt and destroying several meters in the process is the most popular.
- There are also those who design a belt clamping lug and the design is backed up by some form of calculation.
- Here is the problem though. Neither of these approaches is geared towards threading the belting around the pulleys in the system. The lashed system is extremely bulky and there is normally inadequate clearance in the support steelwork for meeting this requirement. The clamped belt lug is primarily designed to pull in a straight line and is at serious risk when subjected to the combined bending and pulling forces when wrapping around pulleys.

4.7 Support equipment for the belt reeler

4.7.1 Splicing station

- In order to build up the total length of belting required for filling the belt reeler, a splicing station is factored into the system. A splice table is erected and a solid structural building erected accordingly.
- This facility will be used during the initial installation of the original belting and subsequent refilling of the reeler once the installation is complete.
- The splice station may then only be used some years down the line when the replacement belting is fed into the system. In all the facility may probably be used up to say 4 times during the life of the conveyor.
- For good quality splicing to be undertaken it is essential that the splicing facility is equipped with humidity control equipment and clean air.

4.7.2 Belt unreeling facility

Figure 10 - Belt unreeling facility

- In order to unroll the length of belting from the reels supplied by the belting manufacturer, an unreeling facility is required.
- The essence of this facility is a cradle type support structure into which the belt reel can be lowered. The reel will have a shaft through the centre which is support on the structure which allows it to be rotated for purposes of taking the belting off.

4.8 Salient points

4.8.1 Maintaining or replacing of pulleys on surface

- In this example the question needs to be raised as to how is the belt going to be handled for taking one of the pulleys out and replacing it at a later stage?
- There are belt clamps situated before the head pulley and after the pulleys on surface meaning that when these clamps are applied one would be able to arrest the tensions in the system enabling one to work on the pulleys.

- In real terms, this is not the issue. The issue is how will it be possible to pull slack into this area to facilitate the removal of the units?
- Cutting the belt and then remove the pulley is a possible option. After the cutting event, where will the length of belting be coming from to now effectively splice and reconnect the two ends? And the amazing part is that there are various of these systems currently in operation with this flaw.
- This problem can be resolved with the installation of a belt storage system. In essence this is a nothing more than a fixed take-up system. The pulley travel does not need to be substantial at all. Having 3m of movement will be more than adequate.

4.8.2 How effective are the belt clamps when used on new belting

- It has been claimed so many times that there is zero movement from certain belt clamp types. Hydraulic clamps versus mechanical clamps and so the argument continues.
- The following is fact. The Conveyor Manufacturers Association has a standard on its website stating that the maximum pressure that may be applied during the clamping process is 2MPa.
- A colleague of the author had a belt clamp tested and certified at the CSIR for safely holding a specific force during the clamping operation. On site he used this clamp only to find that he still had creep in the belt overnight before resuming work the following day. This is a statement of fact.
- Similarly, one was involved with a very reputable client who had all the correct equipment installed for implementing that final splice of the belting on the incline before the head pulley after installation. The words still echo through my mind that there seems to have been a problem with the splice on this belt. The splicing crew may have made a mistake somewhere. All the other splices were non or zero tension splices and only the last splice was done using belt clamps on the inclined section of the conveyor. The splice was made executing under tension conditions.
- Here is the key. The effectiveness of a belt clamp can be proven by means of a straight line. Before cutting a belt under tension, draw a perfectly straight line across the width of the belt. It will be ideal if it can but it is not a requirement that it needs to be 100% square with the edge. After cutting the belt, check for straightness of this line.
- When doing the similar with a belt having wear on it this gets worse. Conveyor belting wears in the middle where it is carrying the material and it is normal for this to happen. As the belt wears more in the centre, the clamping force distributes more unevenly across the width of the belt. The point being made is that clamping takes place more on the outer edges and less in the centre of the belting. To this end the straight line drawn on the belting will have a bow in the middle.
- When splicing a steel cord belt, the thickness of the rubber between the overlapping layer of steel cords, are relatively thin and in certain instances only

1,5mm to 3mm thick. If the bow measured from the drawn straight line differs by 2mm to 3mm, one must realise that there will be an implication once the belt clamp is released. By implication there is a pre-set curve in the splice which will negatively affect impact on the strength of the splice over time.

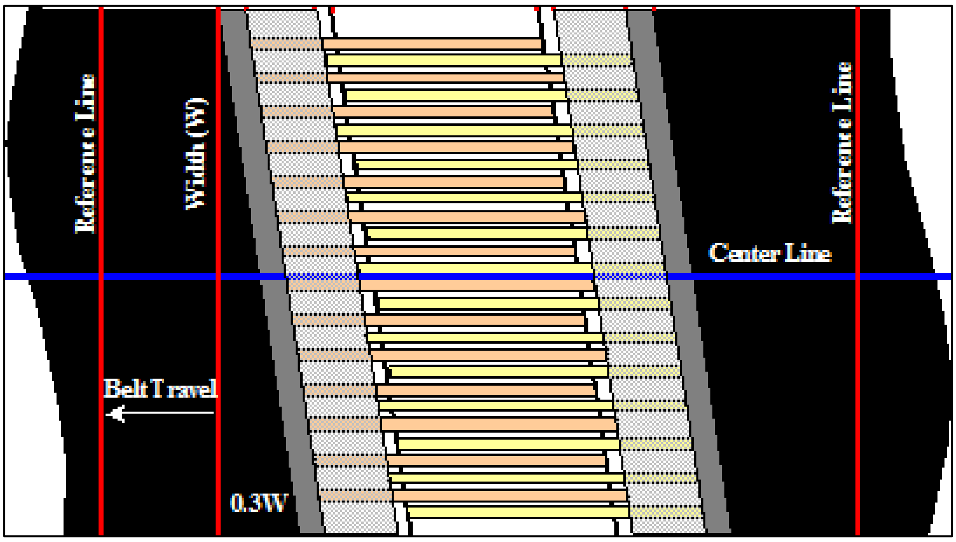

Figure 11 - Plan view on joint

- In this example there are a minimum of 7 splices. Six of these were done at zero tension and one under tension. Should this one splice fail the consequences will be disastrous relative to damage and downtime.

4.8.3 How effective are the belt clamps when used on worn belting

- This issue deserves specific attention as it impacts on the use of the belt clamps after the belts have been in service for a period of time.
- When conducting a visual inspection on a typical section of worn belting, the wear on the belting is not immediately apparent. When viewing a conveyor belt the observer primarily sees the edge of the belt and for the observer the apparent wear is not evident. The belt cover wear occurs towards the middle of the belt and then only in the areas where the material is in contact with the belt covers. See sketch below.

Figure 12 - Section through a new belt

Figure 13 - Section through a worn belt

- The bulk of high tension fixed belt clamps are not segmented and work on the principle of opposing beam type surfaces being forced towards one another across the width of the conveyor belt for applying the required pressure that is necessary for generating the friction and clamping force for holding and securing the belting in place. On applying the clamping force to a worn conveyor belt, the outer edges must first be compressed before the middle portion of the belt will be subjected to a lesser proportion of the clamping force. Similarly, the standard beam deflection profile is such that the deflected distance in the beam itself is more as it approaches the middle portion of the belt. The result of this is that the applied pressure on the edges of the belt will invariably be much more than it is in the centre. It can thus be argued that on a very worn belt the pressure in the middle of the belting could be approaching zero while the outer edge of the belting may be subjected to more than the stated maximum in the belt clamping standard.

- As pointed out earlier, this will lead to the belt having an even greater self induced curve in the cut line when clamped and cut for splicing in high tension areas. Worn belts spliced under these conditions are unlikely to be considered as being of full strength.

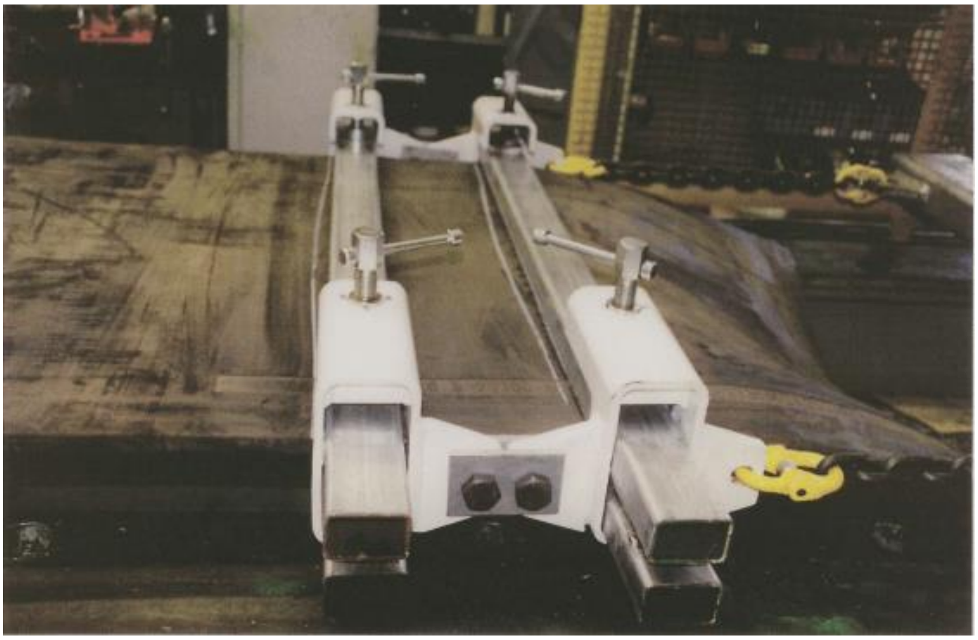

Figure 14 - Curved belt under clamped condition

5 CONCLUSIONS DERIVED FROM THE DISCUSSION

5.1 Belt splicing station

5.1.1 From the discussion it is clear that the splicing station will be used infrequently. That a splicing station is a requirement is definite for developing the initial full length of belting and also for the full length of replacement belting.

5.1.2 It will be ideal and cost effective to only have a short section of conveyor structure permanently installed on a prepared civil slab foundation. This unit can be supplied such that standard idler rollers are drawn from stores to equip the station with the necessary mechanical items on an if and when required basis. On completion of work these items will be returned to stores.

5.1.3 The enclosure required over the splicing station should ideally be a mobile facility capable of being erected on a temporary basis for housing the splicing and humidity control equipment. There is merit in this methodology as it is quite practical for the same equipment to be used effectively elsewhere on the mine.

5.1.4 To maintain this equipment over the extended period of time does not seem practical either. The equipment will be prone to neglect and in the event that it is required to be used, may well be unserviceable for obvious reasons.

5.2 High tension clamping of belting for splicing

5.2.1 The indications are that care must be taken and preference given to splicing belting under low tension conditions.

5.2.2 There will invariably be times where one will not be able to execute a splice in the low tension area for whatever reason. The prime consideration will always remain the ongoing availability and safe operating of the conveyor system.

5.2.3 When required, make the splice under these conditions but care must be taken for remedial action to be taken soonest and for the splice to be corrected and even be remade for reliability of the system. The question going through one's mind is how many times has a splicing team been blamed for making a so-called sub-standard splice?

5.3 Long terms storage of belting

5.3.1 The vertical reeler configuration is ideally suited to satisfy, meet and exceed the requirements imposed by belting manufacturers for extended warranties imposed for long term storage of conveyor belting.

5.3.2 The vertical reeler will need to be housed in a building for preventing unnecessary exposure to and damage from the sun.

5.3.3 The belting can even be turned on a monthly basis which will tie in well with the mechanical items requiring servicing and maintenance. The same applies for the electrical and control equipment.

5.4 Using a belt clamp for letting the belting down the return strand

5.4.1 This is a completely manually controlled system and as such it should only be undertaken and executed by experienced personnel. The downfall of this system is the inherent lag time and reaction time for applying and releasing the braking force. Applying the belt clamp is a manual process applied at normal human reflex speed at most while gravity is ready to react at an acceleration speed of $9{,}81 m/s^2$.

5.4.2 It can be likened to one vehicle pulling another vehicle by means of a long and elastic tow rope. The first problem is to get the tow rope tensioned and pending on the experience of the drivers there will be several jerks and pulls.

5.4.3 The next step is to get both vehicles moving at the same speed. The belting must similarly feed through the belt clamp at a constant speed as it races and brakes from one idler to the next further down the shaft.

5.5 Using a belt pulling winch

5.5.1 Making use of a belt pulling winch is a fairly new concept in South Africa. This replaces the D9 bull dozer approach. With this arrangement the actual tension in the system is finite and quantified.

5.5.2 As noted earlier, the attaching of the pulling rope to the belting is an issue which needs to be formalised. With safety requirements becoming a specific legal requirement the method of attaching can now be formalised and equipment certified accordingly.

5.5.3 The fabricated plate lug bolted to the belting can be designed and rated accordingly for pulling in a straight line. The certification will only apply along the straight line pull. Specific attention is required for pulling the belting around the pulley as when doing this, combined bending moments and other tensile forces are being induced.

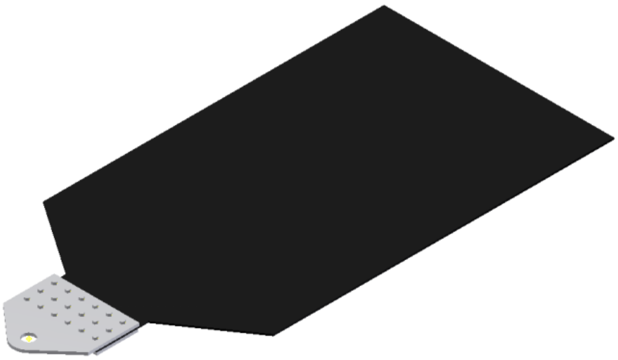

Figure 15 - Fabricated lug – designed but not certifiable

5.5.4 The lashing of the belt end as eluded to previously cannot be certified and is reliant on the supervision of the responsible person on the day.

Figure 16 - Cleat bolted to belting - not certified

Figure 17 - Lashing of the belt

5.5.5 There are systems now becoming available for pulling belting in a straight line as well as around pulleys. These can be rated and certified accordingly for safety purposes.

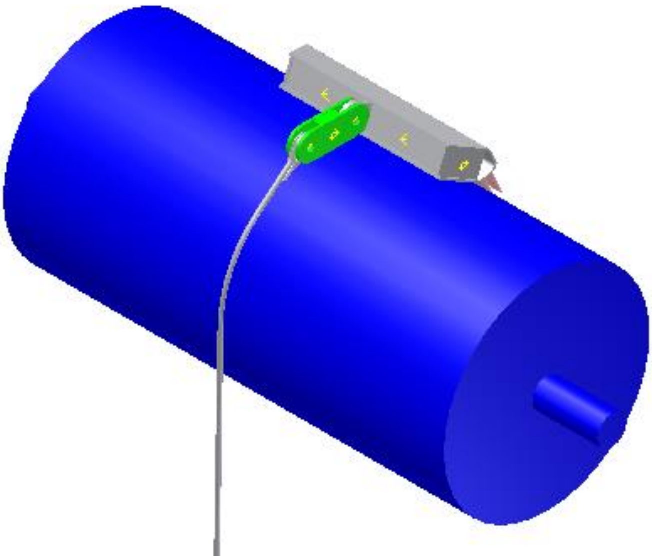

Figure 18 - Purpose designed pulling fixture – tested and certified

6 RECOMMENDATIONS ON THE WAY FORWARD

6.1 Equipment selection

6.1.1 The functional specification(s) for equipment required for handling belting must be clearly quantified.

6.1.2 Ensure that the equipment is adequately sized for the duty. Quantify the required factors applicable to the application which should be site and project specific.

6.1.3 The resultant acceptance criteria to safely operate and utilise the relevant equipment must be clearly stated and supported with certification where applicable.

6.2 Equipment utilisation

6.2.1 Procure all the equipment required for safely handling the belting on site. In addition to this, understand when and how many times the equipment will be used.

6.2.2 In essence make sure to distinguish whether the equipment will be required to be in place as part of the production operations or of the maintenance cycle. When required for maintenance note and tabulate the intervals for usage. This will give a clear indication whether the equipment should be permanently installed or used only if and when required.

6.2.3 To this end the belt storage reeler should be a purpose designed mechanical unit housed in a building designed for protecting the stored belting against the elements.

6.2.4 The belt pulling winch should have a dedicated set of foundations purpose designed and prepared for the application. The winch can be mounted on a subframe thus making it portable to other points on the mine where it can be utilised. The ideal winch will be one as shown in the picture but fitted with a small roof and lifting lugs.

6.2.5 The belt splicing station and belt unreeler will only be utilised primarily for splicing the belting required to fill the reeler. Having the area available for executing the work is a requirement but erecting permanent structures is not.

6.2.6 Permanently installed high tension belt clamps are required on the conveyor in strategic positions identified for belting specific and other maintenance requirements.

6.2.7 Each conveyor application should have detailed belt installation methodology developed and fully documented accordingly. The final methodology should only be put in place after having been subjected to a full risk assessment and hazardous operations study.

6.3 Factors of safety

6.3.1 It is recommended that belt pulling equipment be designed using a factor of 3 as per the CMA belt clamp specification.

6.3.2 The actual pulling force used for pulling the belting into the system should be limited to 150% of the required force. All the relevant attachments and associated equipment must still be sized to a FOS of 3.

6.4 Belt splicing

6.4.1 Belting should be planned and executed in areas where there is zero to very little tension in the belt. This practise will most likely result in splices having at least full strength. Steer away from having belts spliced in high tension areas

6.5 Pulley maintenance

6.5.1 Factor in a facility that will provide slack belt in the high tension area for pulley maintenance.

REFERENCES

- Clamps for belt conveyors document reference number CMA MC01 rev 01 as published by the Conveyor Manufacturers Association of South Africa NPC
- Handbook of Conveyor and Elevator belting published by Goodyear Tire and Rubber Company
- ISO 5048 Continuous mechanical handling equipment – Belt conveyors with carrying idlers Calculating of operating power and tensile forces

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