ZIBULO OVERLAND CONVEYOR CASE STUDY

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INTRODUCTION

Coal from Zibulo Colliery is processed at the Phola Processing Plant, an Anglo Coal and BHP Billiton joint venture operation. Zibulo Colliery is connected to the Phola Processing Plant by means of the Zibulo Overland Conveyor. At Zibulo Colliery, coal is brought to surface by Incline Conveyor CV001 and discharged into a 6 000 t buffer silo. From the buffer silo, coal is fed into a crushing and screening circuit by a second conveyor, CV002. The material is then accelerated to a predetermined speed with an acceleration conveyor, CV003, and transferred to the Zibulo Overland Conveyor, CV004. This configuration allows the Zibulo Overland Conveyor to operate at optimal efficiency conveying coal to the Phola Processing Plant almost 16 km away.

The Zibulo Overland Conveyor is the longest single flight overland conveyor on the African continent. It is also one of the longest single flight overland conveyors in the world. It features three horizontal curves as well as several convex and concave vertical curves. The high vertical lift (176 m) of CV001 combined with the extremely long length of CV004 (15.9 km) necessitated a comprehensive static and dynamic analysis of the entire system.

Static analysis predicts steady-state running belt tension and power consumption for all material loading conditions and also accounts for temperature influences. Dynamic analysis determines belt tensions and power demand during the transient conditions of operating the conveyor, such as starting and stopping. This is used to simulate all motor and brake (or capstan) control functions and integrates their independent control methods with the elastic response of the system, the main objective being to develop control strategies and dynamic tuning methods to limit shockwave forces and belt line displacement to acceptable levels using drive inertia tuning and other methods.

Dynamic analysis utilises a two dimensional wave theory to study time dependant transmission of large local force and displacement disturbances along the belt. The belt is mathematically modelled as a series of elastic springs and masses that deform along the belt's axis. Rheological laws determine the joints between the springs. Damaging shock waves and large local belt displacement, which cannot be determined through static body analysis, can be resolved.

The Zibulo belt conveyors were analysed for a variety of probable load cases and ambient conditions. A number of friction conditions and seasonal temperature variations were considered to ensure an energy efficient and cost effective design. The dynamic analysis was conducted by Prof.dr.ir.G. Lodewijks. Conveyor Experts B.V. (through CKIT).

Figure 1. Crushing and screening plant

Material	**Coal**
Bulk Density	**850 kg/m^3**
Nominal Capacity	**1 750 t/h**
Length	15.9 km
Lift	-16.9 m
Belt Width	1200 mm
Belt Fill	76%
Belt Speed	4.71 m/s
Power (Absorbed)	2 286 kW
Power (Installed)	3 000 kW
Drives	6 x 500 kW
Dual Drive Configuration	2 x Head, 1 x Tail
Horizontal Curve 1	5 000 m radius
Horizontal Curve 2	5 000 m radius
Horizontal Curve 3	6 000 m radius
Belt Class	ST 2500

Table 1. Specifications

DESIGN – ONE OR TWO?

The original design called for two parallel conveyors over the length of the system. This was proposed to ensure optimum availability, as the system only has a buffer capacity of 6 000 t.

The high availability and good reliability of overland conveyors eventually convinced the client to install only one overland conveyor.

Figure 2**.** CV0004 with doghouse sheeting

Dynamic Analysis

The dynamic analysis was conducted to simulate all motor and brake or capstan starting and stopping control functions and integrate their independent control methods with the belt's elastic response.

It also assisted in developing control strategies and dynamic tuning methods to limit shock wave forces and belt line displacements to acceptable levels using drive inertia tuning and other methods. Finally, it was used to analyse and control the cause and effect resulting from operation scenarios such as drive and brake malfunctions.

A dynamic analysis was conducted on the following items:

- Belt (including checking of the vertical and horizontal curve arrangements)
- Drive assembly
- Holdbacks
- Take-up system
- Idler spacing and sizes
- Pulley arrangements and sizes
- Conveyor inertia
- Stopping control
- Starting control.

Dynamic Analysis - Load Cases

For the simulation of the conveyor the following loading scenarios were considered :

- Fully loaded
- Inclines loaded
- Declines loaded
- Empty belt
- Various ambient conditions

Figure 3. Take-up tower and vertical belt turnover

Operational Conditions

The operational conditions determined the type of analysis used. For normal running conditions, a static analysis sufficed, while dynamic analysis was necessary for all other operational conditions.

Operational Condition	Type of Analysis
Normal running	Static Analysis
Normal stop	Dynamic Analysis
Emergency stop	Dynamic Analysis
Operational controlled start	Dynamic Analysis
Aborted start then emergency stop	Dynamic Analysis

Table 2. Types of Analysis

Dynamic Analysis - Belt

During steady-state operation of a fully loaded belt, such as normal running, the maximum belt tension varies between 227 kN and 507 kN. This allows for a safety factor of between 13.2 and 5.9 for the different scenarios. The recommendation was to adhere to a safety factor of at least 5.0 for steady-state; the design was thus well within limits.

For non-steady-state operation of a fully loaded belt, such as starting and stopping, the maximum belt tension varies between 285 kN and 596 kN. This allows for a safety factor of between 10.5 and 5.0. The recommendation was to adhere to a safety factor of at least 4.5 for non-steady-state conditions; the design was thus well within limits.

The selected belt class of ST2500 was therefore acceptable.

The conveyor has multiple vertical, convex and concave curves. The minimum radii for vertical curves used in the conveyor are 3 000 metres in a combined vertical/horizontal curve and 2 000 metres in a vertical curve in a horizontally straight conveyor section. These radii were generously large, providing acceptable edge and centre tensions without belt lift off.

Dynamic Analysis - Drives

The conveyor has three drive pulleys; two at the head and one at the tail. Each drive pulley is equipped with two 500 kW VSD motors for a total drive power of 3 000 kW. The total drive power is sufficient to drive the conveyor at the steady-state belt speed of 4.78 m/s under all operational conditions.

An interesting observation is that this conveyor, under summer conditions and when fully loaded at 1 750 t/h, requires 93% of the installed power based on the compound proposed. In DIN analysis this figure is 88% and with low loss rubber this reduces even further to 75%.

The drives can start and stop the conveyor under most conditions with the demands not exceeding 100% of the available nominal torque. If the system is started with all the major inclines loaded then the torque requirement will temporarily go up to 110%, which is acceptable.

The conveyor can safely transport 2 500 t/h with this design.

Figure 4. Drive station at head end

SAFETY

The majority of the construction of the overland conveyor was labour intensive and remote from the Zibulo Colliery and Phola Processing Plant. Therefore the safety standards and controls were of a high level and regularly monitored, as blasting from neighbouring mines during construction as well as lightning storms had to be taken into account. The head end civil construction took place during the summer where rain also imposed added danger to the workers and equipment. An additional safety officer was appointed to monitor and control all safety aspects in this area.

The steel assembly and erection of the 36 metre rail crossing and 49 metre road crossing required detailed risk analysis and rigging studies to be conducted and implemented to ensure safe erection and construction. Permits and permission had to be obtained from Transnet Freight Rail for the rail crossing (power isolation). The local provincial administration was engaged to facilitate a Stop-Go arrangement while erecting the road crossing.

Notwithstanding all these safety challenges, a good safety record was maintained as well as an excellent working relationship with the customer.

CIVILS

The tail end drive and belt turnover civil construction was completed early in the project and the conveyor route was surveyed with centre line pegs set out every 200 metres on the straight sections, with every sleeper base position pegged in the horizontal curves. A concrete sleeper shutter crew then laid out the sleeper boxes and approximately 40 ready mix concrete sleepers were poured per day.

The first of the concrete sleepers were resurveyed to ensure that the position and spacing was correct. Gradual creep forward in the spacing of the sleepers was identified and the sleeper box interconnecting rods were modified to prevent this from recurring. The sleeper casting process was then continued.

The next challenge along the route were two 36 metre river crossings where concrete bases and footings on each side of a small dam were constructed. A 288 metre environmental crossing was located further along the route, and after much debate it was decided to utilise small three to five metre long screw piles to secure the conveyor structure. This decision to utilise screw piles was based on both time and cost savings.

The next challenge along the route was the construction of the trestle bases and footings to support the 36 metre rail crossing gantry and the 49 metre road crossing gantry. The main challenge was the extremely high water level in this area which necessitated the continuous pumping out of water. Furthermore, it was necessary to go down four metres to obtain an acceptable grounding where rockfill was introduced to facilitate a stable reinforced concrete base.

Figure 5. Overland concrete sleepers

STEEL ERECTION

Space constraints on site resulted in logistical challenges and it was necessary to store approximately half of the overland module steelwork on the Phola site laydown area and the balance at the Zibulo Colliery laydown area. The components were transported by tractor and trailer in batches to site as and when required by the steel erection crew. This crew followed behind the sleeper construction crew. Installation took place in a planned phased approach with a small idler installation crew following the steel erection crew and the dog house sheeting crew following the idler crew to complete the module installation.

Access delays to certain areas were mitigated by moving crews to other areas when necessary. The two 36 metre river crossing gantries, one 36 metre rail crossing gantry, one 49 metre road crossing gantry and twenty four 12 metre environmental gantries (288 m) were all assembled on ground level in position and then erected into the final position via single lifts. All the troughing and return idlers were also installed prior to the lifts.

The 2 000 t silo top steelwork was assembled and sheeted at ground level and lifted into position using a 250 t crane. The first section of the drive house was partially pre-assembled and secured to the hold-down bolts up to the column splice plates. The top section of the drive house was then assembled at ground level and tandem lifted into position with the column splice plates bolted.

The counterweight tower was also assembled in two halves and spliced one on top of the other. The horizontal take-up trolley structure was assembled and erected section by section directly onto the hold-down bolts. The remainder of the head end trestles and gantries were assembled at ground level and then lifted into position.

Figure 6. Gantry spanning public road

MECHANICAL INSTALLATION

The two 500 kW tail end drives and pulleys as well as the tail end belt turnover rollers were installed first. Then the four 500 kW head end drives and pulleys were installed as well as the head end vertical belt turnover rollers. The take-up trolley and other pulleys were installed next. Lastly the belt arrestors, take-up winch and capstan brake were installed.

Approximately half the overland conveyor belts were delivered to the Phola laydown area and the balance was delivered to the Zibulo Colliery. This reduced the handling time as these 500 metre long belt rolls weighed about 20 t each and were difficult to handle. A purpose designed belt trailer which could be towed by a tractor and easily positioned between two modules was manufactured specifically for this project. A portable capstan winch which could also be towed by a tractor was used to pull the belt over the idlers.

The custom built equipment, complete with a dedicated belt installation crew, reduced the belt installation time. When necessary, a belt splicing crew was called out to conduct the splicing.

Figure 7. Belt installation

CONTROL PHILOSOPHY

The correct control philosophy was paramount to the successful operation of the conveyor within the parameters identified during the static and dynamic analysis. Below is a synopsis of the control philosophy:

1. **Starting control**
   a. Operational start:
      i. The belt is started and accelerated to 100% speed in 450 seconds.
      ii. At start-up the secondary pulley is started first. This is the master VSD and slave 1.
      iii. Two seconds after start-up the primary pulley is started. These are VSD slaves 2 and 3.
      iv. These four VSDs follow a 20 second linear acceleration up to 0.2 m/s belt speed or 4.18% speed.
      v. 30 seconds after start-up the tertiary or tail end pulley is started. These are VSD slaves 4 and 5.
      vi. 80 seconds after start-up, the six VSDs together accelerate the belt up to 100% speed.
      vii. The acceleration from 4.18% speed to 100% speed follows an S-curve with a time of 370 seconds.

   b. Aborted start – follows the same procedure as an emergency stop.

2. **Stopping control**
   a. Operational stop: The six VSDs ramp down and decelerate the belt from 100% speed to 0% speed in 225 seconds.

   b. The deceleration follows an S-curve.

    c. If the stop signal is received at a speed other than 100%, for example, 60%, the S-curve is proportionally adapted to provide a quicker deceleration.

3. **Emergency stop**

   The VSD output is deactivated removing power from the motors and the belt will drift or coast to rest.

General Control Philosophy

1. Starting, stopping and speed control signals come from the customer PLC via Profibus to the master VSD.
2. All control signals from the customer or plant PLC only go to the master VSD.
3. Starting, stopping, tripping, interlocking, speed reference, torque control and all other controls of the slaves are part of the internal functionality of the master/follower VSD system. These controls are from the master VSD to the slave VSDs.
4. The emergency stop signals are the only exception to this.
5. Emergency stop signals are hardwired from the field to the master VSD and the No.4 slave at the tail end.
6. Control interlocks that must prevent a start or cause a trip go to the plant PLC.

Figure 8. Sub-station at the head end

COMMISSIONING

One of the interesting problems which had to be dealt with prior to commissioning was the theft of the pull key cable along the route. An extra three kilometres of pull key cable had to be replaced due to this theft which took place after the installation had been completed.

To ensure the smoothest possible commissioning, two separate audits were conducted to check the alignment on the rollers and to check the installation angle of the rollers in the curves.

The overland conveyor was started for the first time on 2 November 2009. Due to the extreme distance between the head and tail end, four teams of six people along the length of the conveyor assisted during commissioning. Their main task was to check for run-out due to possible misalignment. After running for a period of time, a slight misalignment was spotted on the horizontal take-up trolley. To ensure the system was perfectly aligned, the conveyor was stopped to correct this.

Before any work could commence, the conveyor had to be locked out. This took a team of 30 people to first lock the tail drive at the Zibulo Colliery and then lock the head drives at the head end at the Phola Processing Plant. This process took more than four hours to complete. A minor adjustment was effected to the take-up trolley to correct the misalignment.

The conveyor was then started again with no misalignment. No further problems were experienced during commissioning.

Figure 9. Environmental gantry

CONCLUSION

The entire system was successfully completed and commissioned within the expected time frame. The dedication of the team on site and the good relationship with the client allowed challenges to be solved along the way.

The longest single flight overland conveyor in Africa was successfully commissioned on 2 December 2009, and will continue to add significant value to the Zibulo Colliery operation for many years into the future.

In 2010, The South African Institute for Steel Construction awarded the project a Commendation for the exceptional use of steel.

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Rudi Pieterse received his NH Dip. in Mechanical Engineering from the Vaal Triangle Technikon in Vanderbijlpark and also holds an MBA from the University of Potchefstroom. He has more than 15 years' experience in material handling, working with several prominent companies in the field. Employed by FLSmidth Roymec, he is actively involved with, and a director of the CMA.

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