# LONG OVERLAND CONVEYOR DESIGN AND OPERATION

Paul Schutte

Sasol Mining, Secunda, South Africa

## 1. INTRODUCTION

Conveyor belts are one of the most cost-effective means of transportation of bulk materials over short and medium distances. With the need to transport bulk materials over longer distances, and enabled by improving technology, overland conveyors have become progressively longer in recent years. Below are some of the longest belt conveyors in the world.

Table 1: Overland conveyors

| LOCATION | MATERIAL TRANSPORTED | DATE COMMISSIONED | LENGTH |
|---|---|---|---|
| Syferfontein, Sasol Mining, South Africa | Coal | 1991 | 12,3 km |
| ZISCO, Zimbabwe [2] | Iron ore | 1996 | 15,6 km |
| Curragh, Australia [3] | Coal | 2007 | 20,0 km (with intermediate drive) |
| Zibulo, Mpumalanga, South Africa [1] | Coal | 2009 | 15,9 km |
| Impumelelo, Sasol Mining, South Africa | Coal | 2015 | 26,9 km (with intermediate drive) |
| Shondoni, Sasol Mining, South Africa | Coal | 2016 | 20,5 km |

The Impumelelo and Shondoni overland conveyors are currently the two longest conventional belt conveyors in the world.

The Impumelelo and Shondoni mines are two new mines at Sasol Mining that were developed to replace the aging Brandspruit and Middelbult mines.
These two new mines are situated further away from the end user, Sasol Synfuels Operations, than the previously operated mines. As such, a more extensive overland conveyor system had to be developed to ensure an uninterrupted coal supply to Sasol Synfuels Operations. The conveyor from Impumelelo to Sasol Synfuels Operations (Impumelelo conveyor) has been in operation since August 2015 whereas the conveyor from Shondoni to Sasol Synfuels Operations (Shondoni conveyor) has been operational since July 2016.

These conveyors make use of the latest conveyor belt technology which includes variable speed drives, energy saving (low rolling resistance) conveyor belt and user-friendly optimised control systems.

  

This paper gives an overview of the Impumelelo and Shondoni overland conveyors. The Shondoni conveyor design and operation is discussed in more detail and trends observed in the actual performance data are explained. This paper furthermore discusses the unique maintenance requirements associated with long overland conveyors as seen with maintaining the Shondoni conveyor.

## 2. IMPUMELELO AND SHONDONI CONVEYOR DATA

A summary of the Shondoni and Impumelelo conveyor systems is given table 2:

Table 2: Conveyor Data

| | **SHONDONI** | **IMPUMELELO** |
|---|---|---|
| Length | 20,489 m | 26,851 m |
| Lift | -9 m | -56 m |
| Design tonnage | 2400 tph (coal) | 2400 tph (coal) |
| Belt | 1200 mm wide, St-2500 N/mm | 1200 mm wide, St-2000 N/mm |
| Belt speed | 6.5 m/s | 6.5 m/s |
| Installed power | 5 x 1000 kW motors (4 at the head and 1 at the tail) | 4 x 1000 kW motors (2 at the head and 2 at mid-station) plus 2 x 450 kW motors (one at the tail end and one at mid-station on the return belt) |
| Motor Voltage | 690 V, variable speed drives | 690 V, variable speed drives |
| Take-up tension | 20 ton (gravity take-up at tail end) | 12 ton (gravity take-up at head end, with Capstan brake on rope) |
| Horizontal curves | 4000 m, 4000 m, 4000 m, 3800 m, and 5000 m | 10200 m, 6000 m, 4600 m and 4600 m |
| Design and construction by | Sandvik Mining Systems | ELB Engineering |
| Dynamic analysis and control philosophy | AC-Tek (Dave Kruse) | Conveyor Dynamics Incorporated (Larry Nordell) |

  

## 3. IMPUMELELO OVERLAND CONVEYOR

The Impumelelo conveyor route is illustrated in Figure 1.


Figure 1: Impumelelo overland conveyor route

A “tripper drive” is used to boost the power at the intermediate point. The distance of the conveyor from the tail end to the intermediate drive (at mid-station) is 18,4 km, and the distance from the intermediate drive to the head end is an additional 8,4 km.

The trajectory of the first section of the conveyor, up to mid-station, is mostly downhill whereas the trajectory of the second section is then uphill. This change in trajectory necessitated that the intermediate drive be situated closer to the head end and not in the middle of the belt trajectory.

Figure 2: Impumelelo overland conveyor

  


Figure 3: Impumelelo overland conveyor mid-station

Figure 4: Impumelelo overland conveyor intermediate drive

These pictures were taken during the construction phase. Two 1000 kW drives were installed on the carry side belt, at the mid-station, on two pulleys which are in a tripper configuration. At the same location one 450 kW “tripper drive” was installed on the return belt.

  

## 4. IMPUMELELO AND SHONDONI CONVEYOR SYSTEM DIAGRAMS

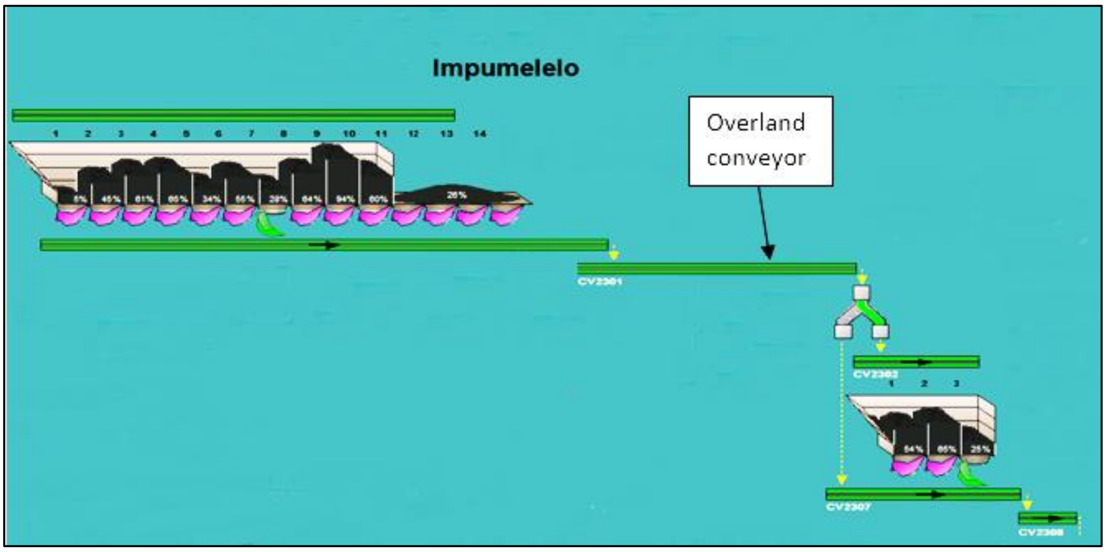


Figure 5: Impumelelo conveyor system diagram

A schematic presentation of the Impumelelo bunkers and conveyors is shown in Figure 5. The bunker and conveyor systems of Impumelelo and Shondoni are similarly configured.

The system consists of a 15000 ton bunker with a 15000 ton "throw-out" stockpile at the mine. The coal is pulled from the bunker from any one of the 14 luffing chutes situated underneath the bunker. The feed rate is controlled by varying the speed of the reclaim conveyor. The luffing chute gives a constant coal profile on the belt (ton/meter is constant). The reclaim conveyor has two belt scales that are used to control the feed rate in a closed loop control system.

The reclaim conveyor feeds the overland conveyor. The overland conveyor head chute can either feed to the 4000 ton bunker, close to the Sasol Synfuels Operations plant, or it can divert the coal to bypass the bunker and go directly onto the bunker reclaim conveyor which routes the coal to the Sasol Coal Supply plant conveyors and stockpiles.

  

## 5. IMPUMELELO AND SHONDONI OVERLAND CONVEYOR DESIGN CONSIDERATIONS

During the early design phase, both the Impumelelo and Shondoni overland conveyors were planned to be two conveyors. However, based on cost, belt operability and coal quality considerations, it was decided to design Impumelelo as a single conveyor with an intermediate drive and Shondoni was changed to a single flight configuration. Below are the most important benefits and disadvantages that were considered.

Table 3: Single conveyor versus two conveyors considerations.

| | **IMPUMELELO: Single conveyor with intermediate drive versus two conveyors.** | **SHONDONI: Single flight versus two conveyors** |
|---|---|---|
| Benefits | Shorter startup time<br>Lower transfer height at mid station.<br>Marginally lower capital cost. | Shorter startup time<br>Less degradation of coal (one transfer is eliminated).<br>Significantly lower capital cost (save the infrastructure cost that would be required for a mid-station drive). |
| Disadvantages | Lock-out process time consuming due to long travel distance between head and tail drives.<br>More complex control system (making use of tension sensors with load cells to control the belt tension). | Lock-out process more time consuming due to long travel distance between head and tail drives.<br>Higher class belt required. |

  

## 6. SHONDONI OVERLAND CONVEYOR

### 6.1 Conveyor route

The Shondoni overland conveyor design and operational performance is described in more detail in this section.

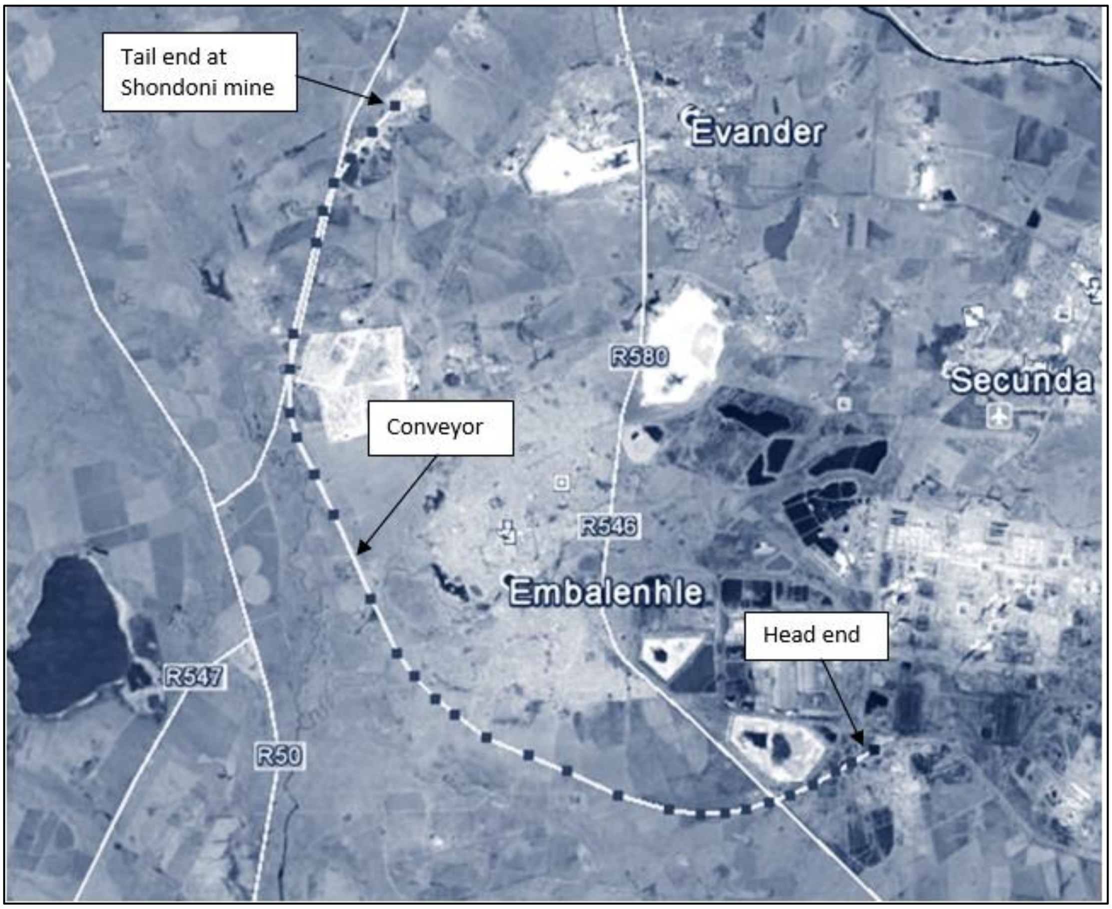


Figure 6: Shondoni overland conveyor route

Refer to the conveyor route indicated by the line with the dots. The conveyor runs with a C-curve around mine dams and residential areas. Most of the horizontal curves have a radius of approximately 4000 m.

### 6.2 Conveyor Design Considerations

1. Dynamic analysis is of critical importance during the design of all long overland conveyors, this analysis predicts the dynamic behavior of the conveyor during startup, running and stopping conditions. This is used to determine maximum tensions, to size the motors and to determine the control parameters and take-up configuration.
2. Conveyor belting with low rolling resistance (energy-saving) bottom covers is used which reduces overall power consumption.
3. Belt turnovers were designed at the head and tail locations to reduce material carry back and spillage. It also increases the life of the return side idlers as it reduces dirt accumulation on the idlers.

  

4. The gravity take-up at the tail end makes provision for:
    - Stretching of the belt due to the change in running tension in belt.
    - Length variation due to temperature changes.
    - Means to release tension and create slack to be able to do maintenance on the pulleys at the tail end.
5. The belt storage (manually operated fixed take-up) at head end makes provision for:
    - Permanent stretch in the belt.
    - Allowance for cutting out and redoing of splices.
    - A means to release tension and create slack to be able to do maintenance on the pulleys at the head end.
6. Belt clamps are installed on the carry and return belts near the head end and near the tail end to hold the belt in position when the tail take-up tension, or front belt tension, is released for maintenance purposes.
7. A 30 ton bin at the head end accommodates overrun of coal due to the difference in stopping time between the overland conveyor and the receiving conveyor.
8. The carry idler is a 3-roller trough idler configuration. The trough angle is 45°. This trough angle was selected as it provides better tracking of the belt in the curved sections compared to the generally used 35° trough.
9. The carry side idlers are spaced at 4.0 m and the spacing is reduced to 3.0 m in all horizontal curve sections which provides better tracking.
10. The return idler is a 3-roller trough idler configuration. The trough angle is 20°. The return idlers are spaced at double the carry side idler spacing. The 3-roller return idler configuration provide better tracking in the horizontal curves than the more generally used V-return idlers.
11. The idler frames are banked up to 7° in the curved sections, as required to ensure that the belt does not run off the idlers during all loading conditions. The radius of the curve, belt tensions and material loading are factors that determine the banking angle required.
12. A 100 kNm brake is installed at the tail pulley.

  

**6.3 15000 Ton bunker at Shondoni mine**

Figure 7: Shondoni 15000 ton bunker

The Shondoni mine incline and tripper conveyors feed into a 15000 ton bunker. This in turn feeds onto the overland conveyor system.

**6.4 Luffing chutes**

Figure 8: Luffing chutes underneath the bunker

  

Figure 9: Lowered luffing chute feeding coal onto the reclaim conveyor

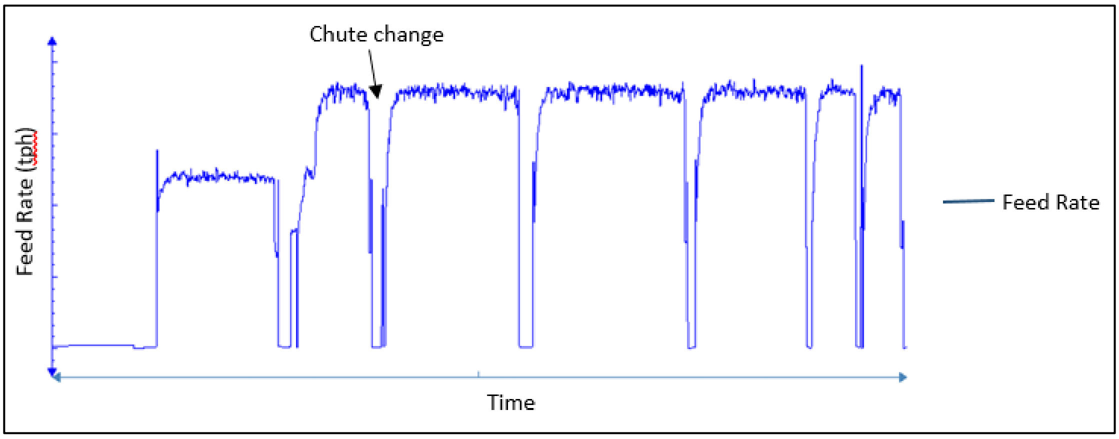


Figure 10: Feed rate from the luffing chutes.

The operation of the luffing chutes is as follows:
Coal is drawn from the bunker and "throw-out" stockpile via luffing chutes (a total of 14 luffing chutes). Only one of the luffing chutes can be open at any time. The feed rate is controlled by varying the speed of the reclaim conveyor. When one chute is closed and the next is opened there is a short period where the feed is interrupted. A belt scale is used to measure the load on the reclaim conveyor and the control system automatically maintains the feed rate at the rate set by the operator in the control room.

  

**6.5 Tail end**

The gravity take-up is at the tail end.

There are belt turnovers on the return belt at the head end and tail end of the conveyor. At the head end belt turnover the belt is turned to face the dirty coal conveying side upwards. At the tail end belt turnover the dirty side of the belt is turned back to face downwards, making it ready to accept the coal at the loading point. By turning the dirty side of the belt upwards, spillage of carry back material at the return idlers is prevented.

Figure 11: Tail end

**6.6 Overland modules**

Figure 12: Shondoni overland conveyor

  

Due to the horizontal curves the idler frames are banked by up to 7° to ensure tracking. A telescope was used to do the angular alignment of the idler frames during construction as shown in Figure 13.

Figure 13: Alignment of idler frames.

**6.7 Head end**

Figure 14: Head end with bin (during construction phase).

There is a 30  ton conical bin at the head end (cast into a rectangular concrete box) to accommodate overrun of material due to the fact that the overland conveyor takes much longer to stop than the receiving conveyors.  This was allowed for in the case of trips or e-stops being activated on the receiving conveyor.

Of further interest is the overhead crane in the building that is used for the lifting of heavy items during maintenance of the drives or chutes.

**6.8 Start-up torque and speed**

The Shondoni control system records all instrument readings, state changes and variable speed drive parameters.  The graphs shown below are actual measurements taken during operation.  The time periods indicated were for specific loading conditions at a specific ambient temperature.  These periods may vary slightly depending on the loading and temperature.

The following can be noted from the graph below:

- It takes 8 min 20 s for the conveyor to accelerate to full speed.
- Initially the four drive motors at the head end are started to 5% speed while the tail drive does not provide any torque and there is no movement of the belt at the tail end.
- After the head drives have driven the belt for 47 s at 5% speed, the tail end speed sensor picks up movement of the belt.  During this period the tail drive still does not provide any additional torque.  The first 47 s of operation goes into stretching the belt until the tension at the tail end is sufficient to start pulling the belt though the tail drive.
- After 1 min 25 s the tail drive motor torque is ramped up until it provides the same torque as the head drive motors.  Thereafter all five motors share the load equally.
- The conveyor speed is maintained at 5% for the first 1 min 30 s. Thereafter the speed is linearly increased to full operating speed.

  

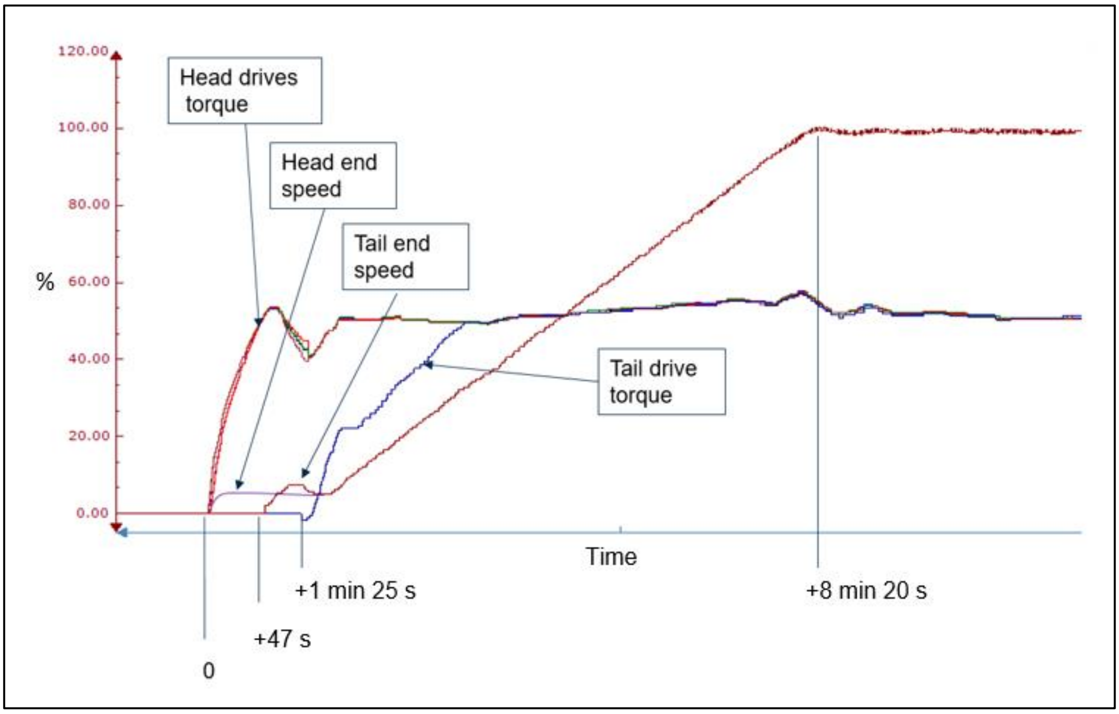


Figure 15: Start-up torque and speed trends

**6.9 Controlled stop**

Refer to the graph below for the torque and speed profiles experienced during a controlled stop.

The following can be noted from the trends:

- The drive torque is ramped down over a period of 21 seconds.
- The conveyor speed ramps down to zero in 1 min 7 seconds.

The brake at the tail pulley, which is proportionally controlled using the velocity feedback, is used to slow the conveyor down and retards it according to the programmed speed deceleration graph.

  

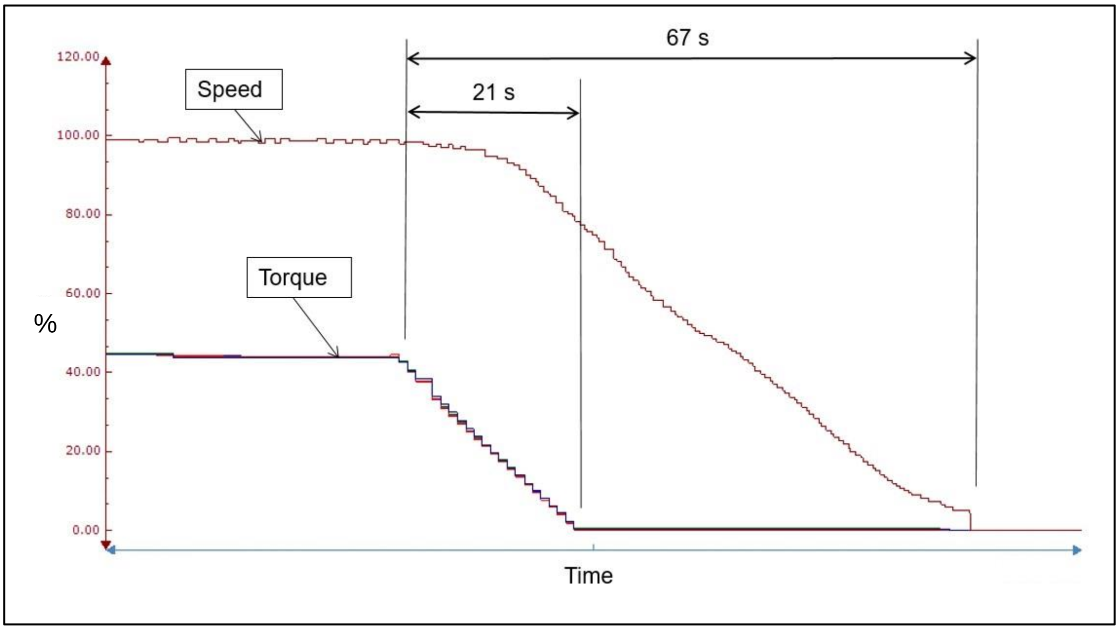


Figure 16: Controlled stop torque and speed trends

**6.10 Emergency stop**

Refer to the trends below of the torque and speed during an emergency stop.

The following can be noted from the trends:

- The drive torque immediately falls to zero when the emergency stop is activated (it is a requirement in the Mine Health and Safety Act, and regulations, that the power to the motors is removed, in case of an emergency stop).
- The conveyor speed ramps down to zero in 50 s.

The brake at the tail pulley is engaged at constant torque (spring applied) to slow down the conveyor to be able to stop it in a reasonably short period of time.

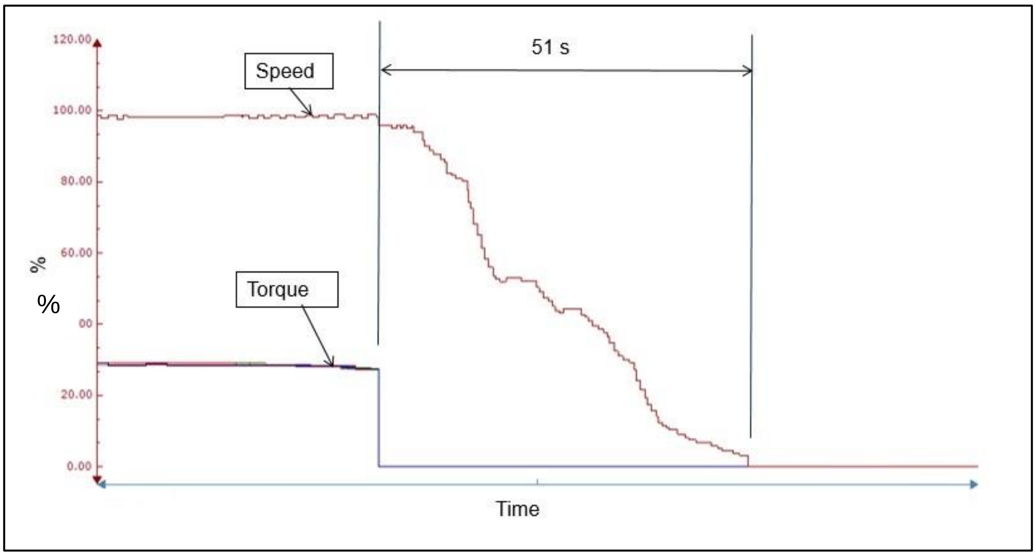


Figure 17: Emergency stop torque and speed trends

  

### 6.11 Speed, load and torque trends

Refer to the trends below. This is a very useful graph. It shows the loading rate (tph) at the loading point onto the conveyor, as taken from the belt scale readings. The total load on the conveyor (tons) is also indicated. All readings are indicated as a percentage of maximum design load/speed. The motor torque is indicated as percentage of motor rated torque.

The following can be noted from the trends:

- It takes approximately 53 min for the conveyor to be loaded fully.
- When the total conveyor is loaded at 60% of the design capacity, the motor torque is at only 40% of the rated motor torque. This means the installed power is more than adequate.

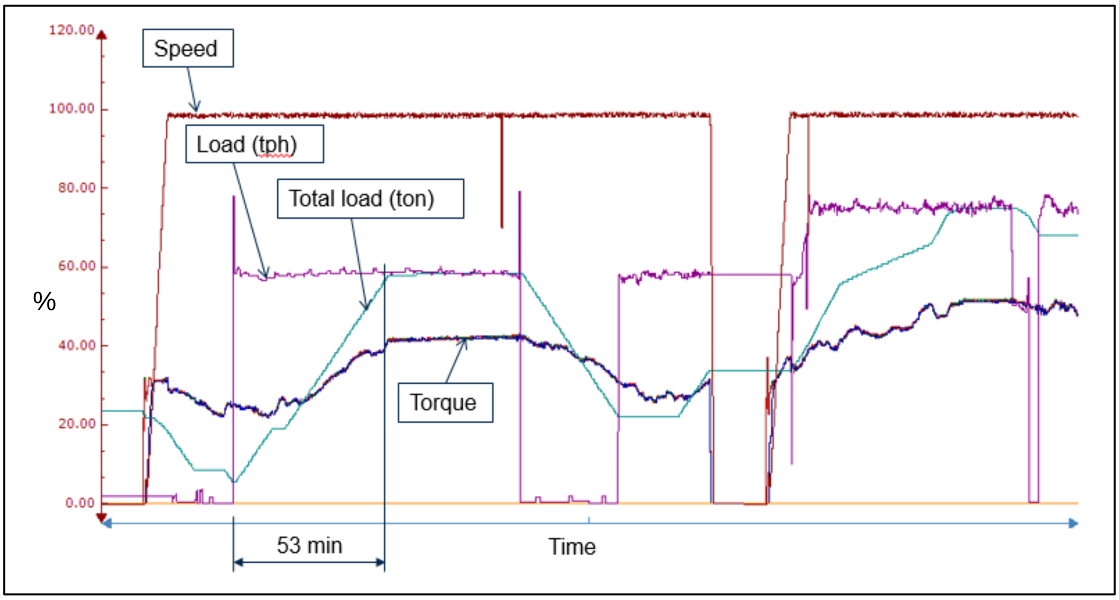


Figure 18: Speed, load and torque trends

### 6.12 Maintainability

Lock-out:

As mentioned, the lock-out process is time consuming due to long travel distances between head and tail drives.

Sasol is currently developing a remote lock-out system for long conveyors that will enable personnel to lock out the conveyor at multiple lock-out stations along the conveyor length.

This lock-out will make it safe to perform tasks such as replacement of idlers, scrapers or instruments without following the normal full electrical lock-out procedure. For major mechanical work and any electrical maintenance, the power will still have to be locked out as it is currently done.

  

Further Maintainability Considerations:
The belt store at the head end can be used to create slack belt at the head end, this is to enable maintenance on the pulleys at the head end. Belt clamps are used to isolate the tension in the overland portion of the belt when tension is released at the pulleys.

The take-up at the tail end can be used to release belt tension to get slackness in the belt to be able to do maintenance to the pulleys at the tail end.

Strong points were installed every 500 m along the conveyor. These are to be used as anchor points to pull the ends of the belt together during belt replacement exercises, or in the unlikely event of a catastrophic splice failure. The conveyor structures themselves cannot withstand the forces of such activities.

Figure 19: Strong points for belt anchoring and pulling

Belt bridges are installed every 500 m along the conveyor where personnel can cross safely.

Overhead cranes are installed in all the drive house buildings to be able to lift heavy items during maintenance activities.

## 7. CONCLUSION

The Impumelelo and Shondoni overland conveyors are two of the longest and most technologically advanced belt conveyors in the world.

There were many unique design, operability and maintainability challenges, as described in the body of the report, which had to be overcome through innovative design solutions.

South Africa can be proud to be one of the countries in the world who are successfully using long overland conveyors to transport bulk material, in a very cost-effective manner.

## REFERENCES


1 Hancock, T (2010). Longest overland conveyor in Africa commissioned in Mpumalanga. (Mining Weekly. 28th May 2010)
2 Conveyor-dynamics.com website. Zisco Project – World record
3 Conveyor-dynamics.com website. Curragh project – World record


## ABOUT THE AUTHOR

PAUL SCHUTTE

Paul qualified as a Mechanical Engineer at the University of Pretoria in 1977.

He completed a MBA at the same university in 1986.

He worked the first part of his career, as a design engineer, project manager, and systems engineer at Denel Aerospace Systems on air defence missile systems development and production programmes.

He joined Sasol Mining in March 2006.

Paul has been responsible for compiling the Sasol Mining technical specifications for bulk materials handling systems. The Thubelisha, Impumelelo and Shondoni conveyor systems were built to these standards.

During the past 6 years Paul was closely involved in the design and construction of the Impumelelo and Shondoni infrastructure.

Paul lives in Secunda, he is married to Hannelie and has three kids.
In his free time Paul enjoys traveling, photography and just being in nature.


**Paul Schutte**
Address: Sasol Mining, Secunda
Mobile: 079 505 7518
Email: paul.schutte1@sasol.com


  