OVERLAND CONVEYOR ASSET DELIVERY

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Operators require to be provided with infrastructure that is delivered on schedule and performs to its nameplate capacity with maximum utilisation. Equipment downtime needs to be avoided as much as possible.

The intention of this paper is to discuss the necessary design, construction and commissioning considerations required to hand over a reliable and robust overland conveyor (OLC) system to the operator.

The case study presented in this paper is a 7.6 km OLC with compound vertical and horizontal curves, which was detail designed, construction managed and commissioned by Hatch. This conveyor was delivered as part of the Grosvenor coal project, Queensland, Australia, for which Hatch provided EPCM services.

1.0 INTRODUCTION

This paper steps through a collection of design, construction and commissioning technical principles that are required and key to ensure successful asset delivery of an OLC.

The case study presented in this paper summarizes the Grosvenor OLC, the model used for its delivery and steps through the various commissioning activities that were carried out and the challenges that were overcome.

2.0 DESIGN

Ensuring that the OLC engineering design is accurate and that it considers all of the pertinent details is essential to successful asset delivery. If the engineering design of the OLC lacks accuracy and attention to detail, this will certainly lead to difficulties during construction and unnecessary adjustments during commissioning which inevitably will lead to schedule and budget overruns.

Some important considerations for OLC engineering design include;

- Conveyor plant layout and route selection
- Conveyor operating resistance calculation
- Ground module design
- Adverse load case analysis

The conveyor engineer should always carry out a study to determine the most appropriate conveyor layout. Even on relatively simple overland conveyors, the study should consider the ideal position for the drives, brakes and take-up. Amongst other driving factors, such as the availability of power and the terrain, the conveyor's dynamic behaviour must also be considered. In many cases, the ideal positioning of this equipment can remove the need for flywheels and capstan brakes, and can increase the stability of the belt on features such as horizontal curves. These properties can be assessed for the different configurations with the 'dynamic' conveyor software modelling tools available in the public domain.

It is critical to calculate the conveyor's operating resistance with a high level of accuracy. If the conveyor's operating resistance is not calculated accurately, this has the potential to result in major issues that are very costly to the project and schedule, such as undersized drives, inadequate structures, incorrectly chosen conveyor banking angle and incorrect belt rating. If a conservative belt rating is chosen, this has a large impact on the operating efficiency/cost of the conveyor.

The calculation of operating resistance due to change in material elevation is a known fact. However, (although technology has improved significantly in the last decade) science is yet to define a method that calculates the operating resistance due to the mechanics of the belt and material travelling across the rollers with 100% accuracy. Additionally, there are a large number of variables involved with the calculation such as temperature, rubber rheology, roller seal and bearing grease properties, idler configuration, idler alignment, belt and bulk material flexure behaviour which are specific for each overland conveyor location and configuration. For overland conveyors that have minimal elevation changes, a significant amount of engineering effort needs to be applied to the above mentioned topics in order to calculate the conveyor's running resistance with a high level of accuracy. It is important that the conveyor resistance calculation is supplemented with, for example, rubber rheology testwork, small scale indentation running resistance test machines (such as those at Hannover/TUNRA) and roller rotating resistance testwork. It is also important that the conveyor resistance calculation assumes a realistic idler alignment.

The conveyor idlers and support structures make up the largest portion of steelwork and have a profound effect on the performance and reliability of the conveyor, thus their design is of extreme importance. To achieve a successful outcome, the design of the idlers and structures needs to consider (as a minimum);

- Idler configuration (e.g. centre roller length and roller diameter)
- Roller deflection absolute, considering all structure.
- Stress (including fatigue)
- Thermal effects
- Natural frequency
- Constructible accuracy

If constructible accuracy is not addressed sufficiently during design, this can lead to significant construction delays and extended commissioning periods. Close attention needs to be paid to the fabrication accuracy of each individual component used in the structure, including the foundations. A trial construction sequence is recommended if schedule permits.

During design, it is also important to consider the potential adverse load cases that could occur, such as a brake hose rupture. Such transient cases are able to be analysed with the use of 'dynamic' conveyor software, and in some instances the results of these cases can lead to changes of hardware (i.e. smaller brake callipers) to eliminate the possibility of equipment or structure damage.

3.0 CONSTRUCTION

Construction accuracy of the overland conveyor is of upmost importance for successful asset delivery. If due diligence is not paid to roller alignment, this is sure to result in unnecessary adjustments during commissioning which inevitably will lead to schedule and budget overruns. Commissioning adjustments do not achieve the same accuracy that can be achieved during construction, which are destined to contribute to unreliable belt tracking and increased running resistance.

The key focus of the construction alignments is on the carry side rollers. Compared to the return side rollers, carry side roller mis-alignment attracts a much larger percentage of the conveyor's overall running resistance. Return side roller alignment can have detrimental effects to the belt/structure, however they are not directly complicated by the addition of material and can be rectified easily during commissioning if required. The carry side construction alignments required for reliable conveyor operation and performance are;

- Roller Squareness
- Centre Roller Height
- Idler Frame Centering

The first step to ensuring roller squareness is to confirm the accuracy of the idler frame roller support tabs. It is essential that the axis of the wing rollers are parallel to the axis of the centre roller. All frames that do not meet specification need to be rectified or discarded. A purpose made jig is recommended, refer to Figure 1;

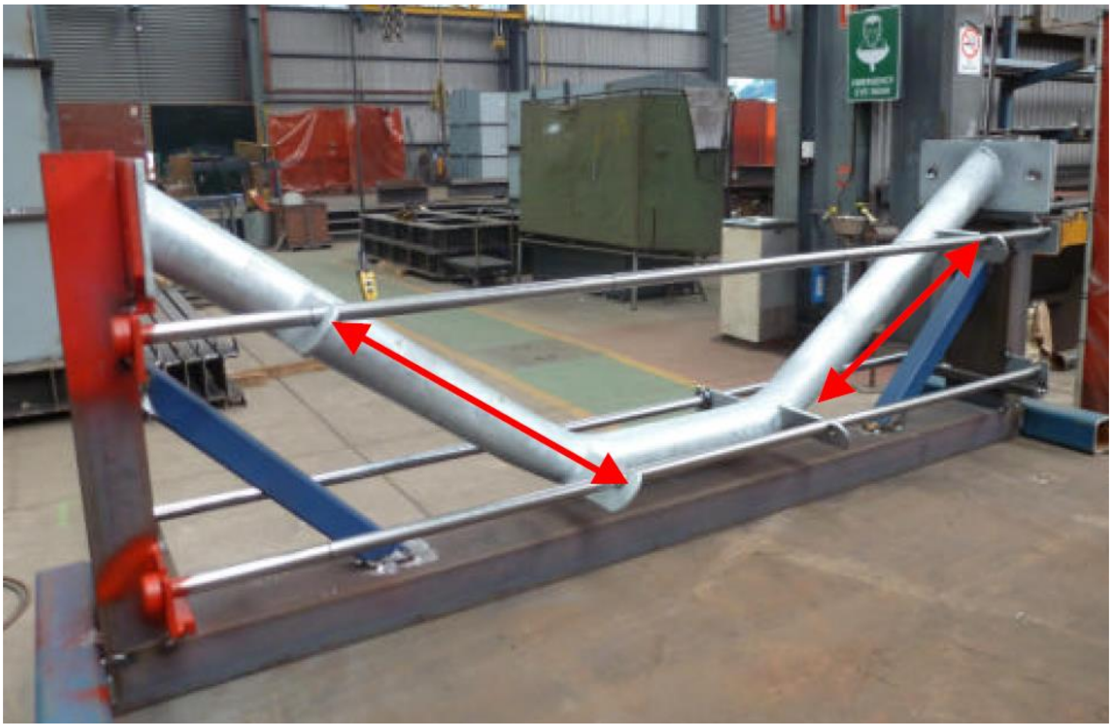

Figure 1 Roller Frame Assessment

The next step to ensuring roller squareness is to confirm the centre roller is set square to the beltline in the field. This can be achieved effectively by using optical survey techniques in combination with a purpose made jig. See Figure 2;

Figure 2 Centre Roller Survey

Optimum alignment is achieved by setting the centre roller square to the beltline. The centre roller is most loaded by the material, and has the most effect on conveyor resistance and belt tracking. However, steering forces from misaligned wing rollers can still swamp the centre roller thus it is important to check the frames as mentioned earlier.

When constructing conveyors at high levels of accuracy, it is important to consider squareness bias. Repetition of even the smallest misalignment in the same direction will effect belt tracking.

Centre roller height and idler frame centering are completed in the field using similar optical survey methods.

It is critical during all stages that the necessary fabrication and construction tolerances of each component (civil, concrete, structure) are achieved to allow unrestricted freedom to allow final alignment of the centre roll.

4.0 COMMISSIONING

Commissioning is the final step in the process before handing the equipment over to the operators. Any mistakes made in this process can have devastating results to personnel safety and to the equipment and/or infrastructure. It is critical to follow procedure and diligently perform all of the required tests to ensure successful asset delivery.

Before commissioning activities commence, it is important to have completed;

- Functional specification
- Commissioning procedure
- Risk assessment (for the commissioning activities)

Without these underlying documents, the commissioning activities will not be planned and this compromises the safety of the personnel and increases the likelihood of damage to the equipment.

The commissioning procedure that is followed is critical to ensure trouble free start up when it comes time to start the belt.

The general procedure for commissioning an OLC should start with setting up and function testing all of the safety and protections systems, such as pull cords, drift switches, rip switches, counterweight trolley limit switches and pulley underspeed switches.

Following this, the engineer should move through each individual piece of equipment on the conveyor (i.e. Pulleys, Brakes and Drive Motors) and inspect and test as much as possible before actually starting the belt. It is important at this stage that all pre-operational inspections are carried out, such as fluid levels, rotation freedom and any special requirements stipulated by the vendor. With the drive motors uncoupled, most of the functions of the conveyor equipment can be tested and rectified where required. This applies especially if the conveyor has brakes.

After each individual piece of equipment is ready, the motors can be coupled. If possible it is best to run the conveyor at a reduced speed (below 20%) for the first time, and then increase in increments up to full speed. This is to minimize the possibility of damage. It is beneficial to take small steps, and test all functions of the conveyor (start, stop, e-stop) at each speed increment, as the risk of equipment damage increases significantly with speed.

Belt tracking can be performed on an “as required” basis remembering not to worry about fine tuning until the conveyor has reached full speed and is loaded with material.

With OLC’s, it is critical to validate the working conveyor against the design calculations. This can be achieved through;

- Taking power readings from the VSD (or current readings).
- Counterweight movements during acceleration/deceleration.
- Pulley speeds during acceleration/deceleration.
- Actual belt speed (time for 1 belt revolution).
- Measuring belt float on the horizontal curve.

Validation of the OLC running parameters is particularly important to ensure that the belt and structures are not exposed to unexpected dynamic tension forces which will contribute to early failures in the future.

5.0 CASE STUDY - GROSVENOR OLC

In this case study, an overview of the conveyor, its control system and the delivery model are provided. The case study then steps through the various commissioning activities that were carried out and the challenges that were overcome.

5.1 CONVEYOR OVERVIEW

The Grosvenor OLC is situated in the Bowen Basin, central QLD Australia. The OLC transports crushed raw coal at a rate of 2500 tph for a distance of 7.6 km. The terrain that the Grosvenor OLC follows is relatively flat, with a net elevation change of 22 m. Some other key parameters are listed in Table 1;

Table 1 OLC Key Parameters

Parameter	Value
Belt Width	1200 mm
Belt Speed	6 m/s
Belt Rating	ST 1250
Horizontal Curve Radius	4,000 m
Installed Drives	3 x 600 kW
Idler Spacing	3/6 m

Shown in Figure 3 is the Grosvenor OLC layout.

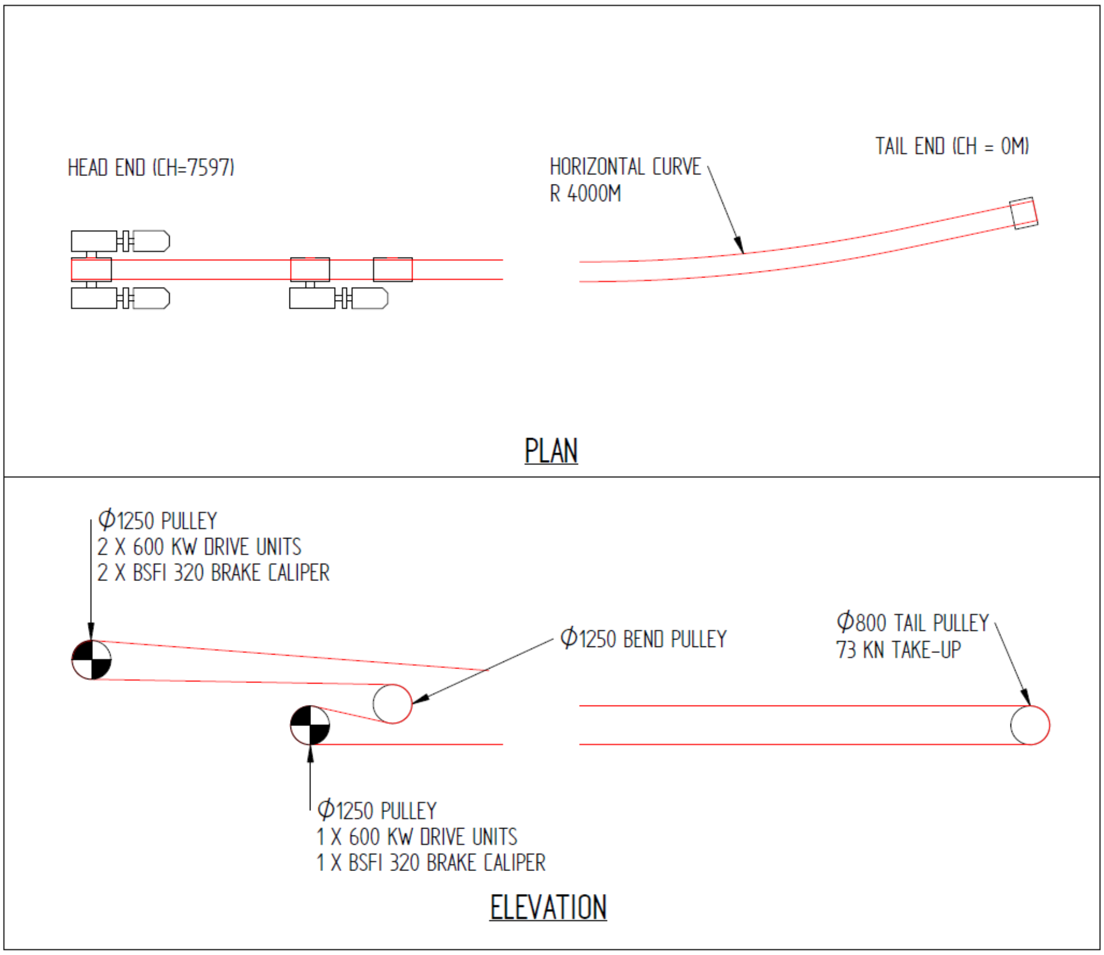

Figure 3 Grosvenor OLC Layout

The Grosvenor OLC Layout is the result of a layout configuration study, which optimised the conveyor's dynamic characteristics and reduced the design tension range in the horizontal curve.

Figure 4 OLC Head End Photo

Through performing the layout configuration study, it was found that there was no overall benefit from the additional of a tail drive. The tail take-up sufficiently controlled the tensions in the horizontal curve allowing it to be workable and the slight reduction in belt rating permitted did not cover the costs for the additional infrastructure required for a tail drive. The added control and reliability complications of a tail drive were also a key factor to the chosen layout.

The Grosvenor OLC required braking to reduce the volume required in the head chute as the following conveyor has a relatively short stopping time. Velocity controlled braking was used, which also helped dampen the dynamic tension waves generated from instantaneous removal of power from the drives.

It was also found through the layout study that additional infrastructure (flywheels, capstan brake) potentially would have been required for a system that had the take-up at the head end. This was due to the vigorous counterweight dynamics observed in the calculations.

The horizontal curve was managed through using a banking angle only, no idler steering or forward tilting was employed (rollers on the horizontal curve were aligned square to the belt centreline). The horizontal curve radius was set such that both the carry and return idlers could be the same banking angle, which simplified ground module design.

The control system architecture used for the Grosvenor OLC is represented in the simplified diagram below;

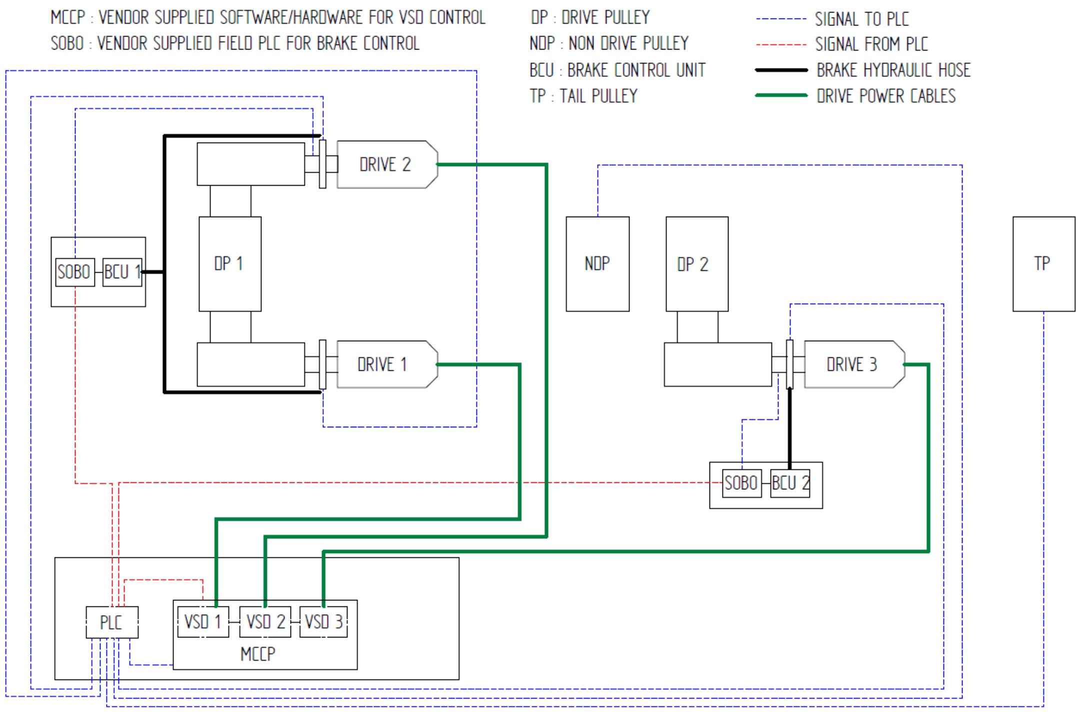

Figure 5 Grosvenor OLC Control System Architecture (simplified)

The control system architecture was designed such that the plant PLC was only required to provide digital signals for operation of the OLC.

The drive torque sharing, acceleration and deceleration ramp control was completed using the VSD drives. The proportional braking torque was controlled using vendor supplied field PLC.

The system was intentionally set up like this to minimize the complexity of the plant PLC, and so that it could be the same between all conveyors. This also assisted in reducing the time required for commissioning.

5.2 CONVEYOR DELIVERY MODEL

The Grosvenor OLC was delivered as part of the Grosvenor coal project using a typical EPCM model utilizing Hatch in-house expertise.

Effectively, the OLC was treated the same as all the other plant conveyors delivered as part of the Grosvenor coal project, however with additional special requirements where applicable. The OLC certainly attracted more engineering design effort, special specifications for procurement and specific tighter tolerances for construction. These additional special requirements were straightforward to manage and caused no complications.

The engineering design of the OLC was subjected to a stringent review process throughout all stages of the project. The design was comprehensively reviewed by several parties, including;

- In house peer review
- External 3rd party audit.
- Client review, whom engaged another 3rd party.

The engineering design documents that were used for the review process include;

- Engineering drawings (profile, ground module structure, etc.)
- Performance specification report (focused on running resistance)
- Engineering calculation report (static, dynamic, horizontal curve etc.)

Using this delivery model facilitated efficiency of the overall engineering effort and interfacing to the procurement effort. All the OLC components were purchased together with existing project supply packages (i.e. belt, pulley, idler, drive, steelwork). This would have been much more difficult if the project was interfacing to an outside vendor. It would have also attracted schedule increases due to additional time required for a tender period and the vendor design period.

In particular, this delivery model allowed the civil works to be seamlessly optimized at any time during the design and construction period. This was important for the Grosvenor Coal Project, as the detailed survey information and soil test works of the OLC path was not available at the start of a project. Having the ability to do this resulted in significant earthworks cost savings.

This model also provided the client with maximum visibility of the OLC design. With any OLC engineering design, it is important to balance capital cost with operating cost. The client was able to have direct input and engagement in the OLC design process, which was not filtered through a 3rd party contractual relationship.

5.3 CONVEYOR COMMISSIONING

The commissioning procedure for the Grosvenor OLC was as follows;

1. Equipment pre-operational inspections
2. Safety/protection systems
3. Brake System
4. Drive System
5. Conveyor No Load Run
6. Conveyor Tracking
7. Brake System Tuning
8. Conveyor Load Run
9. Validation to design

Firstly, all of the equipment was checked for lubrication, functional breathers, free rotation and any special requirements according to the vendor manuals.

The first system commissioned was the safety and protection systems. This included setup and function testing of the pull cords (which need to be tested for compliance with the applicable standard), belt rip switches, belt drift switches, counterweight travel switches and pulley underspeed switches.

The next system commissioned was the brake systems. This involved the following steps in sequence;

- Brake caliper alignment and air gap
- Bleed the air out of the system using the hand pump
- Confirm and test the operation of all switches
- Bump test motor
- Charge brakes and function/leak test
- Confirm settings on hydraulic valves, particularly pressure relief and balance pressure

Following on from this, the drive motors were decoupled. This allowed bump testing, VSD dynamic tuning (which is not necessary but superior to static tuning) and a considerable amount of function testing. Each individual motor was run at full speed, which allowed testing of the acceleration/deceleration ramp, trip testing and emergency stop function.

After the testing was completed on all of the drives individually, all three of the drives were run together and tested. This was to test that all the drives work in unison, especially during trip and that they all wait until they see the last brake lift signal.

The parameters entered into each VSD were confirmed, particularly start ramps and torque limits.

The last test completed before re-coupling the drives was running all three motors at 10% speed (the speed used for the first run).

Next, the drive motors were re-coupled to the reducer.

For the first start of the OLC, spotters were placed at every 400m, and the belt was run at 10%, 20%, 40%, 60%, 80% and then 100% speed. Start, controlled stop and emergency stop was tested at each speed. Also, belt speed was confirmed by measuring the time it takes for a complete revolution.

Due to the pre-work and functional testing of the individual equipment, this exercise was quick and effortless.

A limited amount of belt tracking was required on the return belt. This was carried out safely under drive isolation. The idler bolts were loosened using battery powered impact wrenches which makes the idler adjustment procedure safer and less harmful to the idler frame. No adjustments were required to the carry side. This was expected, since 80% of the effort was spent on carry idler alignment.

Now that the belt has proven it is safe to run, focus was placed on tuning the brake system.

A problem was initially identified due to the stopping time being longer than setpoint (38 s). Initially, the conveyor was taking more than 43 seconds to stop, and the braking was erratic when the speed got close to zero. See Figure 6.

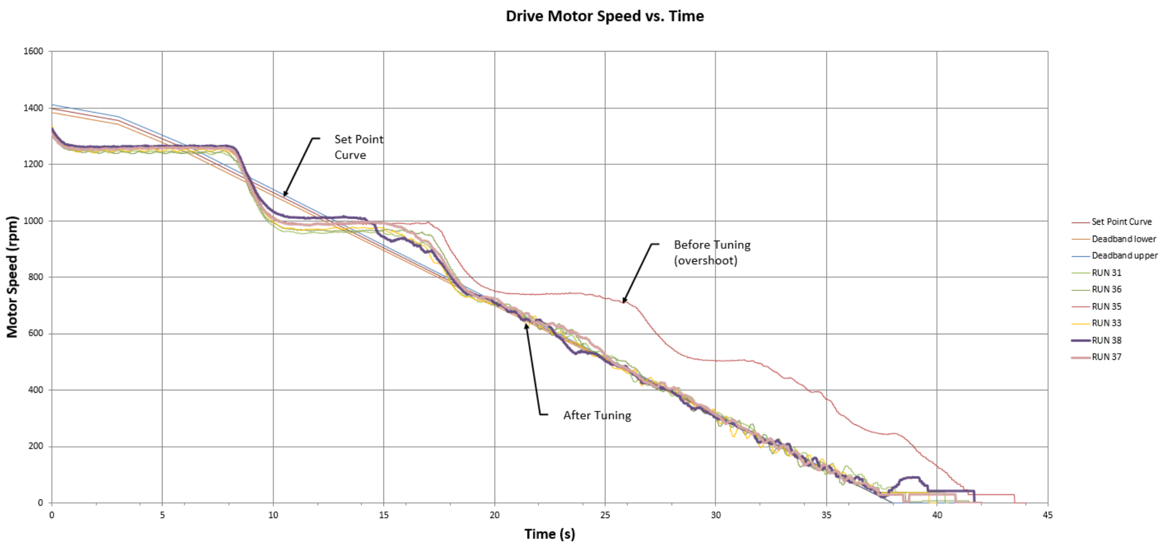

Figure 6 Brake System Tuning (results taken from HMG 3000 portable data recorder)

To assist in the brake tuning process, a HMG 3000 portable data recorder was used to capture pulley speed using an encoder and brake line pressure using a pressure transducer.

By using the results from the data recorder, it was identified that the hydraulic needle valve that controls flow of oil back into tank (to allow the brake callipers to apply) was too far shut. This valve needs to be carefully adjusted to achieve a good result. If it is too far open, brake application becomes rapid and erratic.

Brake control was also improved by lowering the pre-charge pressure in the brake line accumulator. The pre-charge pressure in the brake line accumulator needs to be lower than the brake line operating pressure during braking, otherwise it is ineffective as a dampener.

The brake control unit was also supplied with a back-up 2-stage braking system. The system is designed such that oil bleeds out of a 2-stage accumulator to maintain a constant pressure and once it runs out, the pressure tapers off (hence 2-stage). This accumulator is directly connected to the brake line via a needle valve, and was interfering proportional brake control. A better result was achieved when the 2-stage accumulator was removed.

Fine tuning the adjustment of the balance pressure hydraulic valve also proved to improve brake control. The balance pressure hydraulic valve is active once the brake lift signal is removed, and it is intended that the brake pads essentially just start scrubbing the disk in readiness for application (instead of the air gap) during the stopping period. This makes the brake system more responsive and a better braking control as a result.

Once the brakes were tuned, the conveyor was ready to receive material.

The conveyor was progressively loaded with material, starting at a low rate, increasing slowly up to design rate.

No issues were experienced, and there were no commissioning adjustments required.

The final commissioning activity was to validate the conveyor against its design in terms of;

- Operating Power
- Take-up trolley Movement
- Pulley speeds during stopping
- Pulley speeds during starting
- Belt float on the horizontal curve

The operating power of the conveyor was taken from the VSD output. Shown in

Figure 7 is a trend of material tonnage and power utilisation vs. time.

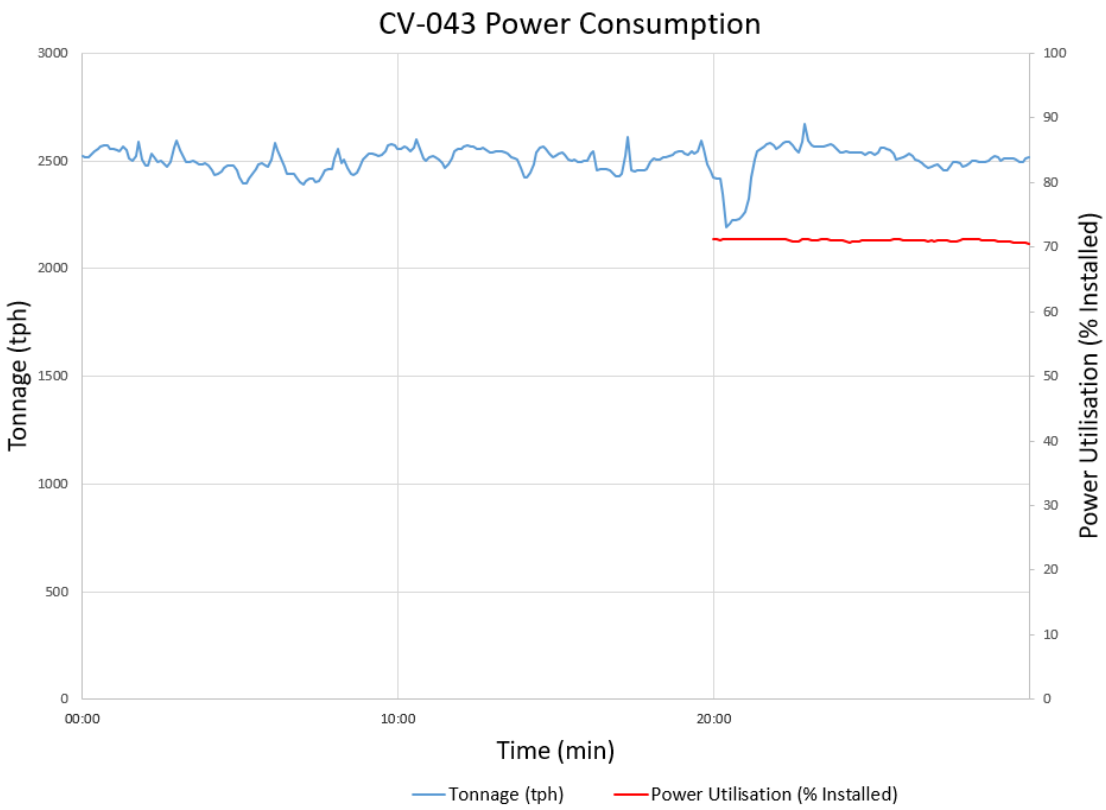

Figure 7 Operating Power Validation

Note that the power utilisation reading has been removed from the graph for the first 20 minutes. This information has been removed since it refers to the conveyor loading previous to the start time of this graph and therefore is not valid, as the material takes 20 minutes to progress from the weigher at the tail end to the head end of the conveyor.

The average power utilisation taken from this graph is 71% with an average of 2505 tph on the belt (equivalent to DIN *ƒ* 0.011). The design calculation predicted a nominal power utilisation of 76% (equivalent to DIN *ƒ* 0.012), which is well matched.

Although a coarse measurement method, this provided enough confidence that the counterweight was not behaving unexpectedly compared to that predicted by the calculations carried out using dynamic calculation software.

The pulley speeds during stopping and starting were assessed from PLC trend data. Pulley speed was measured using flags (8) on the edge of the pulley shell.

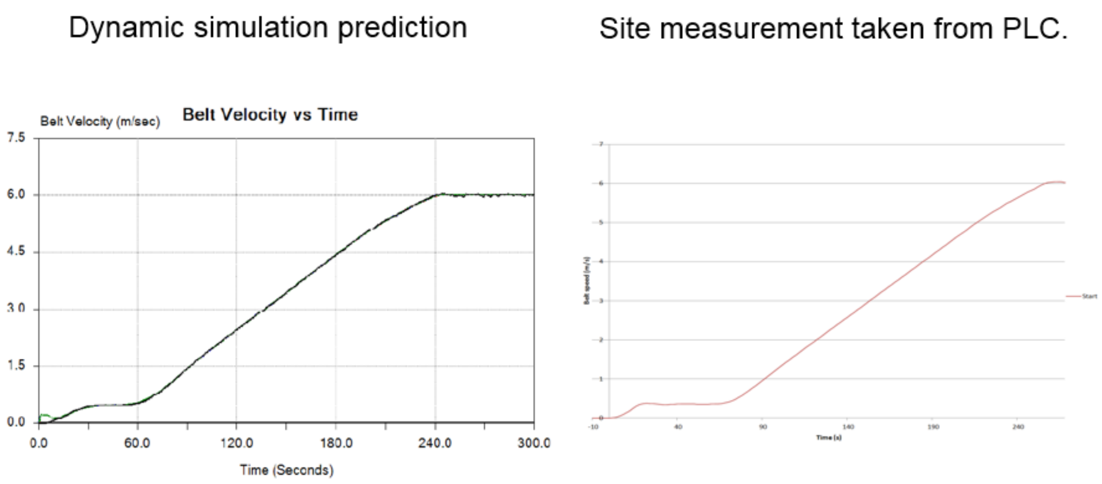

Figure 8 Pulley speed comparison during starting

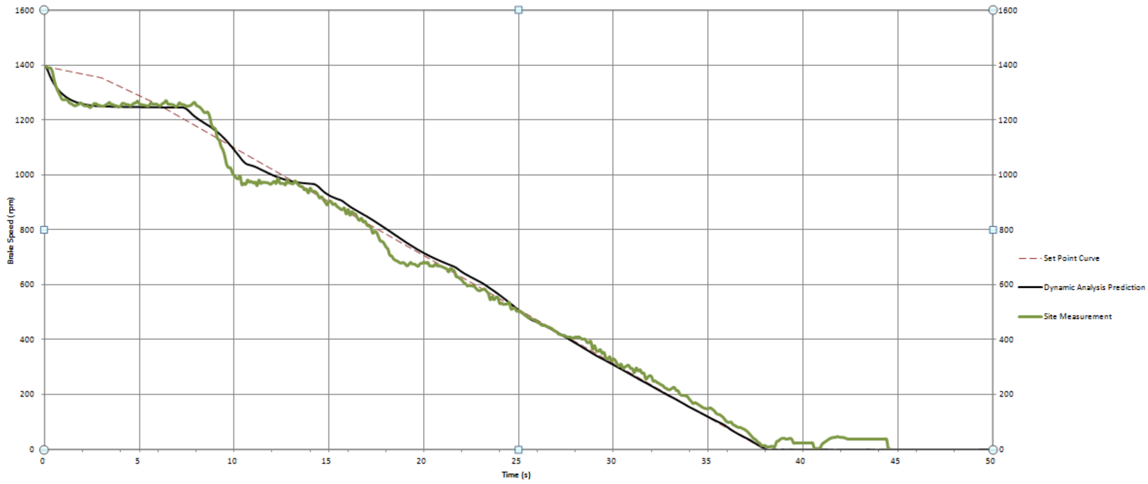

Figure 9 Pulley speed comparison during stopping

As can be seen from the charts above, the pulley speeds operate very close to that predicted by the dynamic calculation software.

6.0 CONCLUSION

This paper has discussed some of the necessary design, construction and commissioning technical principles that are required to ensure successful asset delivery of an OLC.

The case study presented in this paper highlights that the effort and diligence applied at each stage achieves successful hand over to the operators on schedule and within budget.

ABOUT THE AUTHOR

GRANT PORTER

Grant Porter is a Mechanical Engineer with 9 years experience in bulk materials handling both in Australian and International projects. His project experience includes technical design, construction and commissioning of materials handling equipment in the fields of feeding, storage, material flow and conveying.

Grant was the lead engineer in executing the design and documentation, and subsequently was the construction field engineer and commissioning engineer for the raw coal overland conveyor presented in this paper.

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