Optimisation of overland conveyor performance

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Introduction
This paper will explore the key elements to consider when designing overland conveyors to ensure effective capital expenditure, long trouble free life, low maintenance and cost effective operation.

When we talk of conveyor performance we really mean “bang for your buck,” i.e., to achieve the three key components of performance;

- Capability
- Reliability
- Economy

It is easy to spend money to achieve a required transport outcome in a conservative manner; the technology to do that has been around for a long time and unfortunately is still evident today. The demand for a lighter footprint, while achieving the required performance, is becoming more prevalent. Clients with the foresight to pursue this outcome are to be applauded.

Applying what is essentially yard or plant type conveyor design to overland conveyors does the client no favours. The capital cost will be higher, the power consumption will be higher, and maintenance cost will be higher. Additional transfers increase maintenance, increase wear to the belt, chute and load stations and add risk of damage to the belt. All of these things put at risk the continuous operation of the plant.

An overland conveyor designed using the most advanced techniques and materials will provide:

- Reduced capital expenditure
- Reduced power consumption
- Reduced maintenance cost
- Reduced noise levels
- Reduced dust emissions
- Improved availability and reliability
- Improved belt life
- Improved idler life

Discussion
The company today known as Laing O’Rouke Australia (LORA) has a long and successful relationship with Conveyor Dynamics Incorporated (CDI) and have together completed a number of world class overland conveyor installations culminating in the multiple award winning Curragh North Project with a 20km long overland conveyor.

Through persistent research and field measurement, CDI has developed a conveyor design method which examines the visco-elastic properties of the belt rubber cover and the effect of temperature change on power consumption.

The CDI Viscoelastic Rheological Method power equation is significantly more complex than the industry standard empirical methods in common use, and achieves a much higher degree of accuracy which has been proven by field measurement, however this requires an intimate knowledge of the rubber compound in use in the belt construction.

Conventional conveyor empirical design methods were developed a long ago from field measurements of conveyors which looked at the available data of the time.

The power consumption that could not be attributed to known parameters was attributed to the two indeterminate resistances of flexing or deformation of the belt as it travelled between the idlers and the trampling of the material as it changes shape from idler to idler.

Temperature was not considered a major influence on power consumption and some recognised standard methods of conveyor power calculation still do not consider it. Conveyor belt materials other than fabric or steel cord construction were not considered.

It is now clear that the rubber cover compound can be a major consumer of power and forward looking belt manufacturers are investing in research to develop compounds which provide lower drag resistances and an understanding of the varying resistances over the operating temperature ranges.

Benefit of accurate calculation
The benefit of the CDI improved analytical method is not just in calculating accurate power consumptions. It also provides far more accurate information on belt tensions at any point on the belt under any operational condition.

The belt rating required can be selected with greater confidence allowing lower strength belts to go longer distances with greater economical advantage. The standard steel cord belt safety factor of 6.7 is routinely replaced on overland conveyors with a SF around 5.5.

Accurate tension figures for all operating conditions, i.e. load and temperature, provide for the accurate determination
of horizontal curve criteria that permit the operating belt to negotiate curves with gravity as the only external restraint. Side guide rolls are only provided as emergency or transient load condition safeguards. It is better not to guide the belt around horizontal curves by physical restraints, which add drag to the system, increase wear rates and maintenance, and reduce component life as well as increasing risk to the continuous operation of the plant.

Horizontal curves are negotiated by use of idlers banked transversely to resist the natural tendency of the tensioned belt to run in a straight line, ie. to cut the corner.

Accurate tension figures for the range of conditions from typically “low friction-high temperature” to “high friction-low temperature” across the load case range permit accurate determination of the conveyor idler banking angles. To date LORA has not had to adjust the banking angle of any horizontally curved conveyor from the design data provided by CDI. This has a major impact on minimising the time and cost of commissioning on long horizontally curved conveyors, and allows the prompt handover to the client for production use.

Idler life calculations can be looked at for each zone along the conveyor such that the number of idlers installed on the conveyor is reduced rather than using the typical worst case scenario to select idlers for the whole length of the conveyor, which increases capital cost and maintenance simply because there are so many more items in the system.

Belt Flap can cause conveyor component damage and spillage. Determining idler spacing versus belt tension for particular idler roll diameters and speeds during the design period is beneficial in avoiding problems and the need for retrofitting counter measures.

The 20km Curragh North overland conveyor operates at various speeds to suit operational requirements. It should be noted however that the belt speed is not fully variable but operates in five separate speed zones in order to avoid belt flap conditions, which occur at intermediate speeds.
Steel cord belt splice design

CDI advances in splice design allow further economical benefits of belt selection.

It is a curious fact that the belt selection is based on the belt breaking strength when ideally it should be selected by applying a safety factor to the weakest link, i.e. the splice.

Splice designs do vary from manufacturer to manufacturer as does the steel cable construction and the core rubber in use in the belt construction; these affect the pull out strength and the fatigue life of the splice. The fact is, utilising the breaking strength is just a simplified method to cover all variables and as such has to be conservative. The 6.7:1 safety factor for steel cord belts is made up of the assumption of a 140% dynamic or starting tension over the maximum running tension, plus the assumption that elongation, aging degradation of the core rubber, effects of poor alignment, pulley sizing and frequency, and splicing construction errors all add up in effect to a further 100% of the running tension. Added together this gives us a 2.4 multiplier of the running tension to consider.

Hannover University determined years ago that in general a reasonably well constructed belt splice retains 36% of the belt breaking strength after 10,000 cycles.

Therefore 2.4 / 0.36 provides us with the commonly applied belt safety factor of 6.7.

If we consider a belt splice with modern improved design, improved belt construction materials, a reduced dynamic/starting factor and a reduced number of pulleys, the belt safety factor could be further reduced, i.e. more attention to detail yields benefits.

CDI built the world’s largest belt splice test rig and conducted tests on belts up to an ST8800 rating with new designs and new compounds and is now able to replicate those tests electronically. Drive control systems today permit greatly reduced starting factors, and dynamic modelling permits detailed examination of belt tensions under all load cases. This permits preventative measures to be designed into the system to avoid belt tension spikes including flywheels, and proportional braking. Advances by progressive belt manufacturers have greatly improved the pull out strength and fatigue life of core rubbers, and new open construction cables are available that improve the bond strength between the cables and the core rubber.

LORA/CDI have designed and constructed overland conveyors with only four pulleys required. Ignoring the turnovers, on the Curragh North overland conveyor there are only twelve pulleys in use on the 20km system.

Splices have tested beyond 50% efficiency and even beyond 60% in some cases well in excess of the standard 36% used above. Clearly authors of overland conveyor project specifications need to consider these advances and permit the benefits to the project through the use of performance specifications rather than outdated standards and prescriptive specifications.

Idlers

Significant advantages are made available by using wide idler spacing. The most obvious being that reduced quantities equals reduced capital and maintenance cost when selected with the same life expectancy, i.e. usually about 70,000hrs or 10 years L10 bearing life. The Curragh North Overland uses only nine idler rolls in a 10m module.

Larger diameter idler rolls will reduce power consumption due to the reduction in bearing and seal drag effects and add further benefit by reducing indentation losses of the rubber cover of the belt.

Curragh North overland uses 5m carry and 10m return spacing generally with 4 x 8m spacing being used for about 2km, in the low tension zone.

The Warkworth conveyor (Fig 2) uses 4 x 8m spacing combined with tight horizontal curves down to 1200m radius.
These conveyors are not the first to use such wide idler spaces successfully. CDI designed the 15.3km Zisco Conveyor for Zimbabwe Iron and Steel Company with 5 x 10m spacing, and the British Coal Board owned Selby incline conveyor used 5m carry spaces from the 1980s.

Wide idler spacing should not however be used irresponsibly. Detailed examination of the local belt stress resulting at the idler is necessary. Reports of belt surface deterioration developing at the idler high pressure zones have been attributed to high loading combined with wide idler spacing and belt cover rubbers having inadequate resistance to these loads.

A similar type of belt failure was experienced in the early days of thin duck cotton conveyor belting used on light duty conveyors. CDI determines this belt stress for each application to ensure the belt has the prerequisites to fulfil the required duty.

Typically for horizontally curved conveyors longer wing rolls are often used as the belt will move off centre with tension/load changes. These sideways movements are normal for horizontal curves and it is preferable to allow the belt to float rather than to restrict it with side guide rollers. An empty belt will move off centre with only its own weight to counteract the tension force, a loaded belt will run more centrally.

A regularly ignored problem with common idler spacing of say 1.2 ~ 1.5m is that contact with the belt is not uniform due to inaccuracy in the manufacture and installation of the idler transoms. Some idlers sit proud from adjacent ones, meaning they carry additional load and therefore fail early, while others sit just low enough to be skimmed by the belt in such a way that they do not rotate but wear flat spots causing out of balance rolls and vibration. (Fig.7)

This adds to maintenance cost requiring the roll to be replaced and in extreme examples means the same failure can occur in the same place repeatedly. Wide idler spacing guarantees good contact between the belt and all the idler rolls.

Operators today often keep records of replaced idler quantities but rarely do they record the failure location. This information would allow targeting of high failure rate locations allowing the problem alignment to be corrected.

Installation accuracy for overland conveyors or any conveyor belt conveyor for that matter will reduce maintenance costs. A common method of installation is to install the idlers, then pull and run the belt with tracking achieved by steering transoms forward and backward with a hammer. This results in out of line idlers and contributes to higher wear rates of belt and idler rolls and increased power consumption.

Even using an optical device which sits on the wing rolls on either side of the belt to align the idlers, although better than the first method, relies on sightings taken from the most inaccurate location on an idler set where fabrication tolerances are accumulated. Conveyors aligned with all care using this method often still require the attention of a hammer to correct tracking alignment.
The centre roll is dominant in tracking control of the belt and alignment of the idlers should be undertaken before the belt is pulled on. An accurately installed conveyor will provide long life and trouble free operation with minimum housekeeping.

**Conveyor structure**

The most cost effective conveyor structure is one that serves the needs of the mechanical design while minimising the steel and foundations required, balanced against earthworks, drainage and elevated structure requirements.

Clearly a ground level modular structure is more economical than an elevated structure, but only if the cost of the required earthworks and drainage added to the ground structure, is less than the elevated structure installed cost.

As a general rule the more ground structure the better as it improves inspection and maintenance access as well as being more economical. The optimum conveyor structure will vary from project to project to suit the conditions, location, loading, and material to be conveyed. The density of materials as diverse as bagasse, coal, bauxite, and iron ore, with varying lump sizes demand different solutions. To date LORA has not had an exact repeat of any overland conveyor structure on a subsequent project, however lessons learnt on each are carried forward to the next.

A balance must be met between the optimum mechanical design and the practical requirements of an economical structure. Typically, a standard module is determined early in the design process tailored to suit the idler spacing and it must be capable of adapting where necessary to varying idler spacing.

For overland conveyors with horizontal curves the structure has to provide for the banking angles required, which are different for carry and return strands due to tension differences and loads. The banking angles vary along the conveyor for both carry and return strands so considerable flexibility is required within the structure and its installation to permit this.

The typical LORA structure uses a fabricated H frame leg and cold formed stringer sections specially formed to suit requirements. A low height curved roof connects directly to the stringers providing excellent weather protection while adding stiffness to the structure. The result is a light weight efficient structure suitable for the duty required.

With this design the return idler is supported at the leg so the return idler spacing and the leg and foundation spacing is linked. The accurate analysis referred to above is crucial in determining the structural layout for optimum belt performance.

**Loading station design**

Chute design can extend the life of the belt, chute, and skirts, mitigate belt damage from tramp metal, reduce noise, fugitive dust and dust suppression water use. But for the purpose of
this paper we will just look at the benefits to belt wear and the loading profile.

Spoon chutes have been proven to reduce belt wear and are now an accepted part of materials handling. Optimising the chute design requires knowledge and experience of both chute design and the materials to be handled.

The aim of spoon chutes is to match the horizontal material trajectory to the belt speed while simultaneously reducing the impact force on the belt below the rubber yield strength of the belt. (See Fig 10 & Fig 11) An impact force above the yield strength will fracture the belt surface and if the belt is required to accelerate the material up to the belt speed, scuffing and removal of the fractured surface will occur.

The Curragh North loading station (Fig 12) uses a surge bin to even out the flow from the ROM hopper and crusher station, with a variable rate vibrating feeder discharge and a spoon chute. As this conveyor operates at various speeds the most frequently used belt speed was selected for use in the chute design, ie. 6m/sec.

The variable speed design is based on the cross-sectional loading of the belt remaining the same irrespective of the belt speed. In this way the conveyor can speed up or slow down as required by the plant at the head end with essentially instant effect providing delivery at the prescribed tonnage rate. This avoids the delay, which would normally be the case with a fixed speed belt, of changing the feed rate at the tail end and waiting for it to reach the head end.

The major benefit of reduced belt wear is that it allows a thinner cover rubber to be used reducing capital cost. Additionally a lighter belt will reduce power consumption.

Another important consideration in conveyor design is the allowance given to surge capacity on a belt. This is often arbitrarily nominated at 10 or even 20% of the CEMA or ISO recommended cross-sectional loading. This can be a major cost impediment to a project, even at times requiring a wider belt or at the minimum higher belt speeds.

Figure 13 shows the before and after results of modifications carried out on the two Curragh Reclaimer chutes as part of the Curragh Plant upgrade for the Curragh North Project. Both conveyors are carrying the same tonnage but the modifications to the delivery chute feeding the conveyor on the left have provided a smoother load distribution, allowing a higher cross-sectional loading capability and improving plant housekeeping. The pre-existing wine glass shape typical of reclaimer feed is evident on the conveyor on the right.

The capability is available to control material loading to a much greater accuracy than is possible with fixed speed belts.
often considered. The advantage to overland conveyors is a smoother distribution of load which has volumetric space and maintenance benefits. This is valuable for horizontally curved conveyors as there is often some variation in the centreline of the belt to the centreline of the material through curves and maintaining adequate edge distance to prevent spillage is essential.

Fines generation (coal)
LORA in conjunction with CDI conducted a study for a client with a fines generation problem. The mining and delivery method in use incorporated multiple handling and transport methods including shovel, truck, barge and ship, with numerous stockpiling and handling activities in between,
resulting in excessive fines generation, dust emissions and unhappy recipients of the product.

An overland conveyor was proposed to eliminate the haul truck element, and testing of the coal was conducted both in the laboratory and in the field.

Coal of known size distribution was transported along a LORA/CDI constructed 9km conveyor and tested again to determine the level of fines generation (See Fig 14 & Fig 15). Tests were also done where known samples were passed repeatedly through a transfer chute. Bias testing to ensure the material was not adversely affected in the sample handling, sieving etc were also carried out.

The results showed almost negligible generation of fines when travelling on the belt, but significant increase in fines from each transfer chute passage.

This demonstrates the benefit of minimising the number of transfers and running single conveyors as long as can be achieved. It also demonstrated the benefit of chute designs that minimise impact.

**Control systems**

The reliability of conveyors is to a large degree attributable to the advances made since the introduction of solid state technology. There is no doubt the advances in control system technology have played a large part in the successful construction of longer conveyors. Methods of drive torque control over long distances allow load sharing to be achieved for drives 10km and more apart.

However the fact that a conveyor is a long elastic band and each drive pulley does not turn at the same speed does escape many.

Fig 16 is an example of a system installed by a VVVF supplier that failed to provide a stable platform for the belt during acceleration, often resulting in failed starts (shown on the right). Figure 17 shows corrected start.
It is also necessary to understand that the start depends on the previous stop, as the belt retains much of the tension distribution required to stop it under any of the various load and stopping load cases.

CDI has been at the leading edge of conveyor control system technology for many years; its experience encompasses major installations in North and South America, Africa and here in Australia.

**Summary**

Opportunities exist for overland conveyors to deliver benefits to all the participants in the bulk handling industry. Conveyors provide light weight, economical, continuous delivery streams. The domains of road and rail haulage have been pushed back, and it only requires commitment from clients and the realisation of the economies that can be achieved to push further.

Laing O’Rourke is a construction company, not a consultant, but has been invited to perform numerous overland conveyor studies (many of which have turned into actual projects). A recent value engineering exercise resulted in the reduction of belt width by 22%, the reduction of the belt cover thickness by 20% and a reduction in the quantity of idlers in excess of 30% without change to the belt strength, installed power or belt speed on over 4kms of conveyor, providing significant savings to the client.

Prescriptive specifications stifle the innovation potential of “conventional” overland conveyors while alternative single source designs are not subject to industry standards in the same way. Performance specifications would allow the advances made in conveyor design and manufactured components to be more fully realised and drive further development.

Standards by their very nature have to be conservative, but modern accurate analysis permits very significant benefits in the cost of owning and operating an overland conveyor.

The trend for overland conveyors has been to provide lighter and faster systems yielding economic benefits to clients due to the reduced moving mass. Even so the Curragh North overland conveyor “stores” 1,850 tonnes of coal on the belt during operation irrespective of the belt speed at the time.

The trend for ever increasing speeds of conveyors however has stalled some-
alternative idler designs are available with noise reduction capability but more extensive work should be done.

LORA and CDI share a common goal of continuous improvement, which is evident in CDI’s continued development of leading edge technologies and LORA’s delivery of exemplary operational overland conveyor installations, none of which are the same as each other. Systems are specifically designed for the application, with rationalisation where beneficial. Lessons learned are carried forward to the next project.

The best results are attained when all design disciplines and construction methodology are cognisant of one another and use an integrated approach. The design must consider earthworks, foundations, structures, electrical reticulation, mechanical components, construction methods and accuracy along with the conveyor design itself.

Conveyors must be designed with whole of life considerations front of mind: power consumption, maintenance manpower, wear and tear, life of components, and durations between major services with minimised downtime play as big a roll in an economical installation as does the capital cost.

Irrespective of your view on greenhouse gas emissions and the global warming debate, if we consider ourselves good corporate citizens it makes sense to leave a light footprint behind in whatever we do for the future good of the planet, and if we can save money in the process why not.

The author would like to extend his thanks to Lawrence K Nordell, Jean-Luc Cornet and the team at Conveyor Dynamics Inc for the experience gained in working together over many years and for permission to incorporate CDI derived data in this paper.

Recommended references:

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