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Benchmarking continuous haulage

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ABSTRACT: Continuous haulage systems have not always presented a satisfactory operational experience for hard rock or coal miners. Not all mines have used continuous haulage. Some mines presently use one of the continuous haulage systems. Some have tried and abandoned continuous haulage. Yet, continuous haulage offers considerable benefits, which are not always realized. However, there is now a resurgence of interest in these systems as coal mines seek to improve gate road development rates. As most market players are very reluctant to publish information, benchmarking continuous haulage systems can be difficult. This is to the detriment of the industry as a whole. The continuous haulage examples discussed are; bridge, flexible belt, chain, temporary belt support, pipe conveyors and pneumatic systems.

INTRODUCTION

Continuous haulage systems have not always presented a satisfactory operational experience for hard rock or coal miners. Not all mines have used continuous haulage. Some mines presently use one of the continuous haulage systems. Some have tried and abandoned continuous haulage. Yet, continuous haulage offers considerable benefits, which are not always realized. However, there is now a resurgence of interest in these systems as coal mines seek to improve gate road development rates.

Since this paper discusses the benchmarking of continuous haulage, continuous haulage needs to be defined. A definition developed from research is, "Equipment designed and used to obtain continuous throughput of material from the mine face to the main mine load-out conveyor belts; unlike the pulsed, batch load throughput made possible by usage of shuttle cars and battery haulers". This paper is looking predominantly at underground mining, especially the coal mining applications of continuous haulage. There are various designs of continuous haulage systems on the market. Most of these systems are used in the United States. Before use in Australia, the systems need to be modified to meet the Australian Regulatory requirements.

The continuous haulage methods explored in this article will be bridge, flexible belt, chain, temporary belt support, pipe conveyors and pneumatic systems.

SYSTEMS

Bridge conveyor

Most bridge conveyor systems consist of mobile bridge sections; track or wheel mounted and carry chain or rubber belt conveying decks. Bridge sections are typically short (6 m on conveyor bridges and 16 m on chain type bridge systems) and are self-propelled. Depending upon seam (and hence mining) height, the discharge end of these systems can either run over or beside the main conveyor. This enables the bridge conveyor to discharge on the section conveyor as the bridge conveyor follows the continuous miner through the development sequence. Bridge continuous haulage systems provide a haulage system similar to the flexible conveyor train systems.

Bridge conveyors consist of several linked bridge segments using chain conveyors. At each intersection a crawler unit is required, where one operator for each unit might be required. An eighty metre pillar block would require a bridge conveyor with about eight segments and an overall length of 180 m.

The Flexiveyor system (Figure 1) includes a self-deploying conveyor that straddles the section conveyor and loop take up. The conveyor in the Flexiveyor system might have 16 individual cars to a total of 96 m, resulting in a belt advance occurring every 30 to 90 m.

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Figure 1 - Flexiveyor linear mining system (Diversified Mining Services 2010) flexible belt conveyor

Various flexible conveyor trains have been produced including both floor mounted and roof mounted continuous conveyor systems. Both systems offer some degree of operational flexibility. The discharge end of the flexible conveyor runs above the section conveyor. This enables the flexible conveyor to discharge onto the section conveyor as the flexible conveyor follows the continuous miner through the development sequence. The face end of the flexible conveyor is attached to the rear of the continuous miner or is self-propelled and kept at that position. Both roof and floor mounted flexible conveyor systems were trialled in Australian mines during the late 1980's with limited success.

The Joy 4FCT01 (Figure 2) is available in lengths up to 128 m and requires one operator.

Figure 2 - 4FCT01 (Joy, 2008)

Chain conveyor

Chain conveyors (Figure 3) consist of four basic units: a breaker car module, conveyor bridge module, mobile bridge module and rigid haulage system. The system configuration and number of these units depends on individual mine application and production requirements. Systems can be up to 200 m of flexible chain conveyor with a feeder breaker behind a continuous miner. From the chain conveyor the coal is transferred via a belt interface onto the section belt. Chain conveyor systems often have a lower profile and thus are more suitable for lower seam workings.

Figure 3 - Joy continuous chain haulage (Joy, 2010)

Temporary belt support

A temporary belt support system is comprised of a telescopic conveyor utilising a belt bending section and collapsible A-frame belt supports mounted on skids. Temporary belt support systems are available that can facilitate belt extensions during belt operation. These systems allow the inserting of new belt structure and idlers without interfering with production. These systems are used predominantly in low seam mining as shown in Figure 4.

Joy's system requires a take up unit and has a length of 12 m, where CONSOL's temporary belt support system is 80 m long and has an optional take up unit. There is the potential for the continuous miner to be connected directly to the section conveyor when driving the belt road.

Figure 4 - Temporary belt support (S and S Sliders, 2011)

Pipe conveyor

Pipe conveyors are self-advancing and retreating via a monorail system and a hydraulic winch system. Maximum effective haulage length is approximately 200 m. Due to the closed conveyor concept spillage is non-existent. The design relies on a stretchable rubber belt driven by multiple friction rollers acting on a vertically vulcanised drive strip. Pipe conveyors include tear drop conveyors (Figure 5 and Figure 6); both systems use a closed loop of conveyor belt.

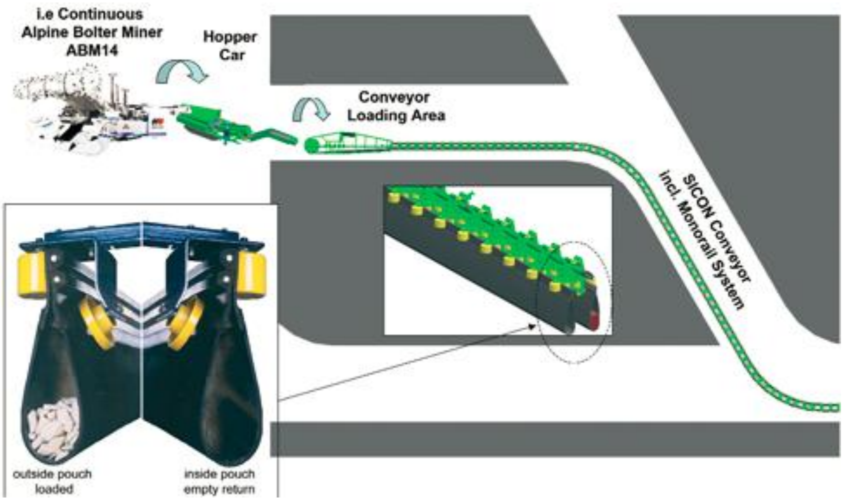

Figure 5 - Vach 500 loading area (Sandvik, 2010)

Instead of running over rollers as a traditional conveyor system would, tear drop conveyors are suspended from a number of idlers on "j" sections that pull the belt into a tear-drop shape for much of its travel. This brings the benefit of enclosing whatever is being transported, removing the need for external structures to be built around the belt to stop dust escaping (Figure 5). Bringing the contents of the belt together helps generate bridging, which stops the material being transported falling back down the belt.

Tear drop conveyors have the ability to handle curves with a radius of about 5 m, much tighter than conventional conveyors. The tear drop conveyor belt only takes the weight of the load but not the tensile load; the "j" sections take the tensile load, and also helping the conveyor to reach an 80-degree elevation.

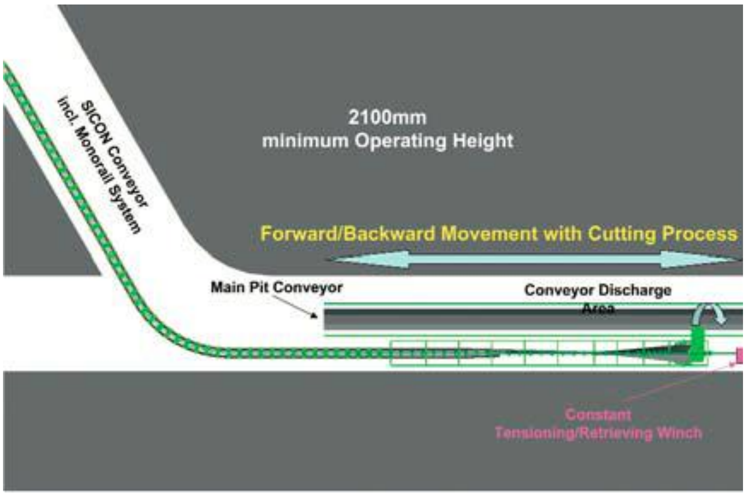

Figure 6 - Vach 500 discharge area (Sandvik, 2010)

This continuous haulage system is supported by a monorail system from a track driven hopper car, which will also act as the loading device for the conveyor system. The hopper car can be equipped with a roof bolter and enough storage space for 100 m of monorail and an inboard lump breaker.

Pneumatic conveyor

Negative pressure (vacuum) conveying systems are ideal for coal recovery because coal can be loaded and conveyed from several faces to a common storage hopper. Coal is loaded directly into the conveying system at the face by the vacuum action of the system. The vacuum system has proved itself in removing slurry and waste from sumps.

The vacuum coal loading system involves use of air injector pumps to generate the vacuum, a separator/surge hopper to remove the coal from the air stream, plastic PVC pipe for haulage and flexible loading tubes for loading the coal at the face.

The vacuum coal loading and conveying system is technically simple and inherently safe. Advantages include operating flexibility, low cost, quiet operation, assists ventilation and ease of automation. This system does not damage the coal particle; though a breaker may need to be placed before the vacuum loading system to reduce oversize.

MINE PLANNING

As sites implement continuous haulage, mine planning needs are to be considered. Besides panel design, the sequencing needs to be analysed and developed to optimise the productivity, recovery and utilisation of the new technology and mining operational requirements. The selection process of the potential continuous haulage systems needs to consider matching mining and outbye equipment production compatibility. To optimise utilisation, the continuous haulage system will need belt moves and installations 'as and when needed'. Since continuous haulage requires a process driven culture, maintenance and operational skills need to be dispersed over all shifts.

Continuous haulage systems are less flexible than batch haulage systems, with mine planning constraints evident where variable geology might be encountered, especially in bord and pillar mining.

When considering wheel driven continuous haulage systems, wider tread pneumatic wheels reduce damage to soft floors. Covers on detection sensors reduce their downtime due to obstruction from dust and mud. Soft floors are damaged more by batch haulage than by continuous haulage systems. Track mounted continuous haulage systems are particularly effective with soft floors.

Continuous haulage systems often can traverse 90^{o} drivage, though 70^{o} angled cut-throughs are preferred to facilitate material handling. This necessitates the formation of diamond shaped pillars, which may in some circumstances be prone to crushing on pillar ends. This may result in larger intersections than would otherwise be preferred.

Other considerations to improve cycle times include: dry and graded outbye roadways, water inflow management, panel move standards, mapping of tasks and resources using Gantt Charts in precise and clear language, and timely feedback for continuous improvement. Water inflow has to be kept to a minimum, pumps have to be installed close to the water sources to protect the road and mud has to be addressed before its formation. This effort is worth the trouble, making most of the other processes faster and easier. It protects the equipment, and keeps the safety and worker motivation higher.

DISCUSSIONS

Some mines have found it necessary to modify or reengineer the continuous haulage system as delivered by the OEM, to enable it to adapt to the specific conditions of the mine. These trial and error modifications have proved quite productive. Some of the other issues encountered with continuous haulage have been spillage and deterioration of minerals.

Spillage can occur as every transfer station is a potential source for spillage. Whilst conveying up to 10,000 t per shift, even as little as 0.1% of spilled material (10 t) necessitates an expensive cleaning exercise. Spillage can make tramming a problem. In confined spaces, manual labour is often the only option to removing spillage. Rubber-belts are prone to retain sticky materials and the application of multiple cleaning stations is in many cases is not technically feasible. Because of these factors chain conveyor systems are more commonly used, but these are prone to wear and tear.

Deterioration of minerals creates fine particles causing major loss of revenue, especially to the coal industry. The more transfer waterfalls, the more fines. Chain conveyors cause an additional milling action, especially in the bottom layers of the conveyed heap.

Although the initial capital costs for continuous face haulage in some instances may be higher than batch haulage, increases in shift production and productivity with continuous haulage should offset these costs. The goal is to increase shift production of coal and reduce operating and accident-related costs enough to justify the initial purchase and long-term use of this technology.

In some mining conditions, continuous haulage may not be just an alternative to batch haulage, but the only means by which some coal seams can be extracted. It should be noted that haulage costs usually makeup 15% to 20% of the total operational cost of a section. Running steel on steel and transporting sandstone-laden ores causes high wear, and may reduce time between overhauls.

The preference for longwall production has highlighted the growing disparity with roadway development. It is necessary to adopt continuous haulage systems to improve the pace of roadway development. If longwall is to reach the operational goal of being fully automated, then continuous haulage in conjunction with appropriate support services such as monorails need to be introduced and developed.

The industry requirements for continuous haulage are:

- Life cycle of the continuous haulage system needs to be capable of performing as specified and seen to be reliable;
- High level of automation;
- Minimal manpower;
- Ease of operation;
- High level of reliability;

- Meet the legislative requirements of Australia;
- Design risk assessment, inspections and test plans to be supplied by manufacturer and may be audited by the mine operator;
- Installation of continuous haulage as a change management process including managing hazards, installation procedures supplied, competency training by supplier, supply of drawings, parts manual, supervised installation by supplier using competent personnel, with fit for purpose tools and parts.

To develop a benchmark for continuous haulage, the systems required are:

- Delivery tests need to include dimensions, observation of operation, record all functions, check all fluid pressure levels, check overload levels, test emergency stops and pilots, test thermistors and RTDs, test fluid flows, review compliance with all regulatory requirements, check polarity, test operational parameters, vibration testing, compatibility with other equipment onsite and check signage;
- Effective communication and documentation systems;
- Providing a risk assessment for operational use with compliance to site procedures, such as isolation;
- Design and operational compliance to Australian Standards, mine site standards and legislative requirements;
- Training compliance gap analysis;
- Mine extraction actual compared to planned, for the continuous haulage system panels;
- Mine schedule actual advance compared to plan;
- A significant change in safety and productivity;
- Opportunity for the OEM and customer mine operator to partner in design, development, and implementation of a safe and efficient system of work;
- Recognise and action the requirement to reengineer existing methodologies for advancing and retreating panel services (systems, equipment and procedures);
- Review current production and maintenance process monitoring measurement and analysis for application to the continuous haulage system operation;
- Determine appropriate set of Key Performance Indicators (KPIs) in establishing continuous improvement program.

CONCLUSIONS

The 'optimal choice' in any analysis is not always made for monetary reasons. Often decisions are made for safety, operational ease or the optimisation of engineering design.

Continuous haulage takes personnel out of shuttle cars, reducing ergonomic issues. Continuous haulage equipment implies safer operation, with relatively less movement of mine personnel and mobile equipment in the face area.

When compared with batch haulage systems, based on the removal of loading times alone, continuous haulage can achieve increases in the utilisation time. Continuous haulage takes the batch haulage bottle neck out of the coal clearance system.

Bolting constraints need to be addressed to complement improvements in continuous haulage. This may require significant design changes to the "bolting machine that mines coal" or the "miner that bolts". The first principle of design demands consistent steady state production rather than peak throughput capacity.

Continuous haulage systems are required to complement the current equipment and roadway dimensions used on mine sites. Continuous haulage systems are not yet completely compatible with present development practices. Currently, a common effective mining cable length is 200 to 300 m. Since cables and hoses on the monorail can be extended only so far, this effective length needs to be considered when selecting the pillar length and should be a multiple of the pillar length. If not the monorail has to be relocated more often than necessary.

To improve continuous haulage, issues to be addressed on site include communication, education and the scheduling of tasks. The benefits of scheduling analysis should be able to show potential options for decreased costs, improved productivity, safety and finally increased return on investment.

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