Technical Article-6

ZERO ENTRY MINING IN SURFACE MINING OPERATIONS

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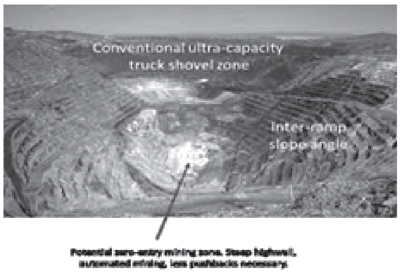
ABSTRACT

Zero entry mining operations are designed so that no-one need ever enter a mining zone. There is a strong business case to apply zero-entry mining in large surface mines that are exploiting ore bodies which are open at depth, or are mining zones subject to considerable risk. This study seeks to identify the gaps in current automation capability in order to achieve and to sustain zero-entry mining operations as applied to surface mines. The study also concludes that there is a need to develop an automated (or remote controlled) multi-functional platform capable of performing a wide variety of tasks, from geological grab sampling or as a mobile sensor platform along with assisting in moving lighting and communication infrastructure, electrical transformers and cables etc.

1. INTRODUCTION

In the last decade, mining and associated companies have made great progress regarding the introduction of autonomous haulage and blasthole drills in large bulk-mining surface operations. However, there are a number of mining operations around the world where geotechnical or geothermal hazards greatly restrict mining operations. An ideal solution would be the ability to extract material from these zones without anybody ever having to enter the hazardous zones. This is known as "zero-entry mining". Zero Entry Mining not only reduces risk exposure to personnel, but can also be a significant source of added economic value through higher utilization of equipment, reduced services (e.g. ventilation) and increased revenue through access to difficult to mine areas. for example, involve exploitation of ore at depth with steep pit walls, or mining underneath unsupported ground 2 which may involve unacceptable risk for personnel to enter the mining zone. Ultimately zero entry mining will enable the complete re-design of mines, mining equipment and mining methods in ways that were not possible if personnel were in the mining zone".



Large metalliferous surface mine with ore deposit open at depth

In particular there is a strong business case to apply zero-entry mining in large surface mines that are exploiting oroboides which are open at depth (see Figure). In such mines, conventional extraction with large capacity equipment would proceed until the ultimate pit limit is attained. Then, using a zero-entry mining approach, smaller capacity autonomous systems could be used in conjunction with steeper inter-ramp angles near the base of the pit in order to scavenge remaining reserves There are many processes in conventional mining operations that require human intervention. Despite the great strides that have been made in mining automation, many gaps exist to achieve the ultimate goal of zero-entry mining in surface operations.

2. Objective

In Australia and elsewhere have changed the perception of risk in some parts of the mining industry, as well as accelerating the pace of adoption of digital technologies by the industry. This paper discusses these changes as well as progress towards resolving the previously identified challenges to zero-entry mining.

3. CURRENT AUTONOMOUS CAPABILITY

As applied to surface mining, autonomous capabilities are currently limited to blasthole drills and truck haulage. A number of companies have developed autonomous capability for blasthole drills, including Epiroc, Sandvik and Caterpillar. However, whilst rotary, pulldown and propel and navigation functions have been automated, some gaps exist even within the capabilities of commercially available drill rigs. One such gap is the ability to discriminate top-of-coal in overburden and interburden applications. Australia currently has some 220 autonomous haulage trucks (AHTs) in operation, the largest fleet in the world. The principal suppliers of AHTs are Komatsu, Caterpillar and Hitachi. Interestingly, at the recent CIM conference in Toronto, Hitachi Mining and Construction announced that they intended to open their operating system to other vendors to facilitate greater interoperability between equipment from different vendors. Sandvik (Mining Monthly March 2019) has also committed to opening up its underground automation to other manufacturers through an API. One of the difficulties encountered with AHTs concerns loss of satellite signal. The Global Positioning System (GPS) works if four satellites are visible. Due to the extreme geography (mountains etc.) or very deep pits, it is possible for trucks to move into a satellite shadow. One solution to this is to employ positioning systems that can work with both GPS and GNSS, the Russian positioning system. Another solution is to employ a number of pseudosatellites which provide an artificial satellite signal to supplement those satellites in shadow. Zero-entry mining activities at the base of a deep pit may have to consider the additional expense of investing in a number of pseudo satellites to supplement GPS and GNSS

4.1 Surveying - Pre-dig preparation

In many conventional surface mines a surveyor is responsible for establishing dig limits on mining benches as well as delineating grade and contaminant zones. Typically this requires that the surveyor use stakes with different coloured tape. Modern GPS dig control systems installed onboard diggers can replace the need to stake out ground. Dig zones can be updated and downloaded via the mine intranet system to the diggers. The Argus™ shovel monitor from Komatsu Mineware is one such system (see xx). Thus technological solutions exists to assist pre-dig surveying, however some mines will need to invest in such systems if they desire to move towards zero-entry mining. Ultimately remote sensing 5 and augmented reality providing remote operators or automated systems with accurate geological or grade boundaries whilst operating will be needed.

4.2 Surveying - Surveying - Post-dig reconciliation

As benches are extracted it is necessary to reconcile extracted tonnes with the short term mine plan. This is done in order to control costs and to adjust for any deviation from plan. Some work has been undertaken on LIDAR scanning systems fitted to shovels in order to provide reconciliation (see Williams &McAree, 2008). However, the resultant maps are used to update the situational awareness of the shovel, and have not been fed back to update the mine plan; this provides and interesting possibility going forwards. The other alternative is the use of drones to fly over dump and excavation zones in order to reconcile material movements. Drones are now regularly flown in some large coal operations. There is no technical impediment as to why they cannot be applied to zero entry operations in surface mines. Applications such as Glass-Terra's Live Terrain take survey inputs from multiple inputs such as equipment and stationary LIDAR, drones, as well as manual survey reading to maintain a single Digital Terrain Model (DTM) that is then made available for all applications.

4.3 Geology - Data capture and sampling

In zero entry mines, it will no longer be possible for mine geologists to physically map or to collect chip samples from drills. Instead, a means of automated sampling or sensing whilst drilling or in hole after drilling will be required. This might be achieved with a general purpose mobile robotic platform with an adaptable tool set. Either this could be remote controlled or have some or all functions automated. An early prototype of this approach (as presented at Austmine 2019 Conference) is being developed by CRC Ore in conjunction with Imdex and Orica using a Universal Field Robotics platform as part of their Instrumenting the Bench initiative.

4.4 Engineering - Geotechnical stability assessment

As mining progresses new structural controls may be uncovered that require geotechnical assessment. In zero entry operations, a drone will have to be used to examine walls. However, 3D perception is required in order to assess the strike and dip of structures. Thus the drone will require a dual camera system in order to provide images in stereovision for a geotechnical engineer to interpret.

4.5 Operations - Wall control installation

Should a geotechnical assessment identify a high risk of failure, it may be necessary to install form of wall control in terms of bolts and mesh. This would require development of an automated drilling and bolting unit. Some R&D work has been carried out on autonomous bolting systems for underground applications by CRCMining.

4.6 Operations - Blasting services

Companies such as Orica have developed systems that combine GPS systems onboard explosive trucks with digital blast designs to control the loading of explosives into blastholes. However, priming a blasthole by inserting a detonator into a booster and lowering these into the blasthole is currently still a manual process. Some years ago, some R&D work was undertaken by CRCMining for the Savage River mine in Tasmania to enable remote priming of holes. This was in response to mining in the presence of an unstable hanging wall. More work needs to be undertaken here to enable automated priming. 6 The tie-in process to connect the blast pattern via NONEL tubes and delays is another process requiring dexterous manual hands. This is a case where some out-of-the-box thinking may be possible such as wireless detonation. Currently, a wireless initiation of explosives carries a risk of accidental detonations, particularly in the presence of stray electromagnetic fields. It is postulated that a dual frequency system may provide for greater safety and permit wireless detonation. This, in turn could eliminate the requirement for connection via NONEL tubes.

4.7 Operations - Autonomous digging

A muckpile of broken rock is an extremely unstructured environment for automated digger. Each bucket load taken from the muckpile causes a reorientation of the muckpile. Although much work has been done on automated LHD and front end loading, there is currently no system on the market that will manage unsupervised loading of shovels or hydraulic excavators. In addition to the tactical simultaneous location and mapping (SLAM) capability required to excavate a muckpile, autonomous diggers will also require mission planning algorithms to optimally guide them to extract a full bench.

4.8 Operations - Refuelling Refuelling of AHTs

could be conducted outside of the zero-entry autonomous zone, however this will contribute to a loss of production hours for the trucks. As with most large pit operations, it may be expeditious to adopt an in-pit refuelling strategy. This will require an autonomous refuelling strategy. Again, this gives rise to an opportunity to rethink refuelling; might it be more expeditious, for example to change out an entire fuel tank rather than trying to located and connect fuel hoses automatically?

4.9 Operations - Interoperability

A barrier to the uptake and interoperability of autonomous mining equipment in the mining industry is the lack of an agreed set of standards across the industry. OEMs employ different bus structures and there is little agreement on standard communication protocols. Toward this aim, the Global Mining Guidelines (GMG) group has established a number of working parties. GMG was first established by the oil sands operations in Alberta, Canada, but has grown in scope to encompass representatives of many of the major mining houses and OEMs. A supplement – and perhaps an alternative - to the development of interoperability standards is the concept of developing an “air traffic control” system for surface mining operations. Under such a system, the near surface land and airspace would be divided into different zones, with permission for machines to enter zones strictly policed by supervisory control software. Such a project has been put forward as part of a new Cooperative Research Centre bid around the introduction of Industry 4.0 concepts into mining.

4.10 Operations - Road and bench maintenance

To optimise AHT and digger performance and life expectancy there is a need to maintain haul routes and bench surfaces in good operational state. In a zero entry mine, this will require automated motor graders and wheel dozers. Whilst GPS is routinely used to enable “grade to design” on motor graders, it has not been used for direction and steering control. Thus, there is some development work necessary here. Opportunity exists to use 7 the sensor data from AHT (e.g. Strut pressures and

LIDAR) to identify areas requiring road maintenance and spillage.

4.11 Maintenance - GET replacement

As with lubrication and filter replacement, it may be necessary to replace wear parts such ground engaging tools (for example, dipper teeth and adapters) in the field. This, of course, assumes that rapid change out buckets cannot be employed, as such buckets can be returned to a central workshop for repair and reconditioning. Again, a new generation of dipper and bucket lips may need to be designed to suit autonomous change-out of ground engaging tools from first principles.

4.12 Mining services - Recovery systems

The reliability of equipment operating in zero-entry mines can be likened to mission critical applications, such as twin-engine extended range operations for airliners. This demands revised thinking on how to assure operations over a campaign life. However, inevitably some equipment failures will occur in-pit. It will then be necessary to recover the failed equipment. For a start, this is only feasible if equipment is size suitable to recover. Thus, large and/or ultra capacity equipment may be ruled out in zero entry operations. A remote controlled recovery rig would be required to tow, or transport, equipment out of the zero-entry zone. Something like an oversized airport tug can be envisaged, or a remote-controlled flat bed.

4.13 Mining services - Pumps, power, lighting

Continuous provision of services such as lighting, power and pit dewatering are a routine consideration of any mining operation. With regards to electrically powered equipment, there is a need to move transformer stations, relocate cable bridges, move cables, all of which may best be performed in a zero-entry mine under remote control. Although it may seem strange to maintain lights in a fully autonomous mine, a lighting station can double as camera pod and/or a communications station to enable supervision of mining operations at night and in periods of low visibility. There is a need to develop a remotely controlled multi-purpose services vehicle to enable these tasks. Such a vehicle could be extended to cover basic service inspection and maintenance tasks. Some work has been done in remotely controlled service vehicles for underground mines by Inco in Canada (Now Vale) and CSIRO in Australia.

CONCLUSIONS

There is a strong business case to apply zero-entry mining in large surface mines that are exploiting oroboides which are open at depth or are mining zones subject to considerable geotechnical or geothermal risk. This study seeks to identify the gaps in current automation capability in order to achieve and to sustain zero-entry mining operations as applied to surface mines. The study identified a list of fourteen initiatives associated with mine geology, surveying and engineering, operations, maintenance and mine services. By considering the applicability of these automation initiatives to current surface mining operations, a suggested development time frame is suggested for developing solutions to these gaps. It is interesting to note that operations initiatives (such as interoperability) take priority, as these have an immediate applicability in current surface mining operations. The exception to this is Ground Engagement Tools (GET) replacement robotization where there is a clear OH&S benefit. Surveying, Engineering and Mine service initiatives have lower development priority. There is a clear warning here for the mining industry not to neglect the development of these applications The study also concludes that there is a need to develop an automated (or remote controlled) multi-functional platform capable of performing a wide variety of tasks, from geological grab sampling to assisting in moving lighting and communication platforms, electrical transformers and cables.

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