MEETING FUTURE MINERAL RESOURCE DEMAND BY ULTRA-DEEP MINING

BY DOUGLAS MORRISON

Deep underground mines, more than 2500 m below surface, are challenged to develop the technologies required to deliver the metals that the industrial economy requires to support a growing global population. A population of nine billion will certainly strain our agricultural and transportation capacity, but it is the total resource demand of the first-world life that threatens to out-strip the resources of the entire planet. The problems that mining face are increasingly complex requiring an in-depth understanding of topics like thermodynamics, tensor analysis and advanced computation consequently, to get much better at moving millions of tonnes of ore every day in thousands of mines around the world, mining needs a lot more physics and the involvement of many more physicists.

THE CEMI AND UDMN ADVANTAGE

CEMI is a Canadian not-for-profit organization, mandated to lead step-change innovation by introducing new practices, procedures, tools, techniques and technologies to help generate a significant improvement in the performance of mines. CEMI focuses on innovation in four strategic technical mining categories: exploration, deep mining, improving mine productivity or operational performance and reducing the environmental impact to improve sustainability. Market acceptance is essential to successful innovation and CEMI diligently works to ensure that these mining innovations are commercially viable and achieve a level of operational integration into day-to-day mining activities. Our approach is purposeful, to ensure innovations are sustainable and economically feasible for the mining industry. The UDMN is a $35 million national network hosted at CEMI consisting of 76 active members from large mining companies to small to medium research and development companies with a total of 25 projects underway that address challenges of mining at depth and are commercially viable for adoption into mining operations.

The UDMN focuses on four distinct areas of research and development that are considered vital to the future success of deep mining: improved human health and effectiveness to enhance the human environment in deep mines; material transportation and productivity to increase the rates of development and production in mines; rock stress risk reduction to improve the stability of deep underground excavations and energy reduction to reduce the energy consumption of mining projects.

IMPROVED HUMAN HEALTH AND EFFECTIVENESS

As the working environments become more extreme there is a measurable decrease in worker productivity. Physical stressors are a commonly encountered impediment experienced by workers in mining environments, but especially increases as the mines get deeper and even more so within the ultra-deep mine setting. There is a need for an enhanced solution to develop more effective personal protective gear that will help keep people working within appropriate occupational conditions. Normalizing temperature and environmental conditions in the extremes of hot and cold air flows including fluctuating oxygen levels and high concentrations of diverse contaminants are essential. One must meet ambient air quality standards so as to not alter or impact human health or performance. Developing systems and technologies that improve communication, navigation and the overall well-being of the ultra-deep workforce is a priority for a workforce that is expected to be productive under these extreme conditions. The current research of interest on improving human health in ultra-deep mining

SUMMARY

This article showcases some of the projects completed by the Centre for Excellence in Mining Innovation that focus on the development of new, commercially viable Canadian technologies. The Ultra Deep Mining Network is a Business Lead Network with matching funding from the federal government comprised of large corporations, small to medium sized enterprises and academic institutions tasked with the selection and supervision of projects relevant to the future of deep mining. In virtually every project the concepts and research is based on the fundamentals of physics and employ physicists as part of a multidisciplinary team.

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environments are: workplace ergonomics and human Factors for Ultra-Deep Mines; workplace safety and industrial hygiene; thermal Control — to design novel systems and technologies that regulate the temperatures to which workers will be exposed and communication and navigation — to improve systems of communication and navigation to effectively communicate with workers over a wide geographical area underground.

Jannatec Technologies managed two projects: thermal garment adaptive wearable mining technology to normalize the environmental conditions in which a worker is asked to perform his job duties and wearable communications to mitigate occupational health and safety risks as our operations move to ultra-deep mining. Maestro Digital Mine has commercialised environmental air quality stations for deep mining. Maestro has evolved from a research and development start-up to a successful manufacturer of gas sensors with the unique ability to be able to be calibrated on the surface with reference gases and then brought to depth without the requirement to re-calibrate at depth. Vigilante AQS™ environmental stations are being installed in some of the deepest mines around the world. These projects are heavily dependant on applied physics and the use of advanced sensors which we understand is one of the divisions of the Canadian Association of Physicists.

Resource extraction in Canada is occurring at ever greater depths and geotechnical risks are increasing significantly, particularly as they relate to stress within the rockmass. The challenges associated with this, in both the mining and oil and gas sectors; need to be addressed as failing to do so will foster unacceptable project risks. This in turn will impact investment and will jeopardize Canada's competitiveness.

INDUCED SEISMIC HAZARD MITIGATION IN ULTRA-DEEP MINES

The in-situ stress due to the overburden increases as depth increases and the redistribution of stress that is a manifestation of mining is more complex at depth. For the safe extraction of minerals from deep mines it is absolutely critical to minimize geomechanics-related risks, which can impact on operational productivity, cost management and safety. The incidence of stress related ground failures increases and are more energetic as the stresses increase due to the depth, these rock burst events can render entire sections of the mines inaccessible. These events are dangerous to the personnel and may have serious negative economic impacts and potentially mine closures due to the so called sterilization of ore reserves. Mine sequencing and de-stress blasting are currently used to modify the stress field and reduce the seismic hazard in deep mines but these techniques are often insufficient to adequately reduce rockburst potential and related risks in mines, in particular near vulnerable underground excavations. Thus, further complementary and innovative research into stress management methods is required. Projects in this theme that will explore ways to better measure, anticipate, mitigate and manage and even modify built up stresses in the rockmass, resulting in more intelligent rock mechanics design protocols and advanced approaches. Cross-sectoral research proposals are looking at ways to make mines safer by reducing geotechnical risks through a broader understanding of the stress management in ultra-deep mining sectors in the next ten years.

There are six current projects underway or near completion in this research area a brief description of a few are as follows. Seismic stress inversion undertaken by ESG Solutions to apply a newly developed method for characterising the direction and stress magnitude ratio stress tensor from microseismic source mechanism results, leading to advanced analysis and interpretive capability. Symboticware developed the open geotechnical data network and data analysis system, which uses appropriately equipped mobile equipment to transfer data from ultra-deep geotechnical networks into a centralized data handling system and thereby enable real-time decision-making, which has just been selected for a multimillion dollar contract to install symbots by Vale an international multifaceted resource corporation with nickel and copper assets in Sudbury, Ontario. Geoscience Integrator, a 4D real time geotechnical hazard assessment and reporting system for ultra deep mining has been commercialised by Mira Geoscience. It is a true 4D multi-disciplinary geoscience data management solution, interfacing with visualization, modelling, query, and expert system applications to drive exploration and mining success. It enables the management of multi-disciplinary time-based data (primary data that is a function of time and the time-evolution of both data and models) in a flexible and easily extensible relational data model. Standard data import, ad hoc reporting, customized standard reporting, and report scheduling are all easily controlled from a web interface. The Institute of Mine Seismology (IMS) embarked on a project to provide active seismic monitoring for seismic risk reduction by turning sensitive velocity measurements from an active seismic source into an in-situ measurement of stress changes in a volume of rock. These geotechnical based projects for the most part involve a deep understanding of the wave nature of seismicity and tensor analysis which naturally lies within the purview of physicists.

IMPROVED MINE PRODUCTIVITY AND NOVEL TRANSPORTATION METHODS

Mining companies are continuously striving to improve the economics and efficiencies of each of the processes involved in getting their product to market. Typically the mine operates with a single shaft, although there may be separate compartments for personnel and materials this is a bottle neck, which becomes increasingly tight as their operations expand further underground; thus, it becomes critical to find innovative materials handling improvements, because it will take longer to transport workers and materials into the mine and to the work place. Similarly, the transportation of ore, waste and fill material into and out of an ultra deep mine present an ever-increasing challenge as mines go deeper.

The main research areas of interest focus on improving mine productivity and introducing novel transportation methods are about improving the individual steps involved in the basic mining activities such as the development process to create the access tunnels or 'drifts' needed to mine the ore. This means improving the cycle of removing the newly blasted rock at the face of the drift, installing ground support to stabilize the new section of drift, drilling the face-holes in the end of the drift and charging them with explosives ready for blasting. Other aspects that are targeted for cost reduction efficiencies include the supply ventilation, pumping water and other fluids, installing services such as power and water, communications, mine planning and surveying (without GPS).

There are seven projects currently supported by the UDMN in improved mine productivity with a few outlined below. The rapid lateral development canopy Phase II is a CEMI project to enable increased development rates by maximizing the utilization of the advancing face. The canopy is a structure that protects equipment and people in the drift heading and allows face activities and ground support installation to be done concurrently, so reducing the critical path cycle-time. Advancing more rapidly access ore sooner and generates revenue sooner, providing a better return on investment. The Hydraulic Air Compressor (HAC) Demonstrator is an Electrale Innovation, MIRARCO and Laurentian University supported project and has grown to a pilot scale project located at Dynamic Earth supported by the UDMN, IESO, NOHFC and Reasbeck Construction to name a few. A hydraulic air compressor exploits the pressure head of water falling in a cylinder to create bubbles of compressed air — as was the case at the Taylor plant in Cobalt, Ontario in 1910. The plant had no moving parts and produced enough compressed air to operate all the pneumatic equipment in all the mines of Cobalt until the last one finally closed in the 1980s. The new hydraulic air compressor plant is intended to determine efficiencies of a system using pumps rather than the natural waterfall of the original.

Finally, the MIRARCO schedule optimization software tool called SOT-plus is a computational method that employs numerical solvers to establish the impact on the NPV and productivity of variations in the long term planning of mining deep ore bodies, allowing profitable and successful mining at depth in the presence of geotechnical, ventilation and asset allocation challenges.

IMPROVING THE ENERGY CONSUMPTION PROFILE OF DEEP MINES

This initiative is intended to develop energy saving methods and technologies to reduce the energy consumed by mines and specifically for Ultra Deep Mines. The energy required to power underground mine operations is significant and is comparable with that used for a city of a few thousand people. The goal of this focus area is to be realized by innovative measurement, auditing, benchmarking and optimization of energy systems for ultra deep mines and innovations in the fields of energy measurement systems, audit methodologies and consumption metrics, realized in hardware, firmware or software that specifically address the needs of ultra deep mines. The target is to reduce the energy demand of the underground ventilation system and the ore transportation equipment. Some targets are to examine alternatives to diesel powered haulage systems, the development of more efficient vertical transportation of ore and rock, and the implementation of energy storage technology in combination with renewable energy systems and novel air-cooling systems. The Cryofan© project for ultra-deep mine chilling is being prototyped by CanMIND Associates and is the topic of a separated article in this edition.

There are seven projects currently funded by the UDMN in collaboration with various industry and academic partners several of which are outlined below. McGill University has studied large scale freezing-on-demand with a closed loop geothermal system. Two projects concern the development of prototype electric powered vehicles, one for personnel transport and a second large-scale battery-powered vehicle in the 150 to 250 hp range; an industry-first. To learn more about these projects visit www.miningdeep.ca.

The projects outlined in this article employ the fundamentals of physics including mechanics, thermodynamics, energy, seismicity and tensor analysis. The mining industry has traditionally employed engineers and accountants to develop projects once the ore deposit has been prospected and delineated by prospectors and geologists. The advances in the technologies required for the mining projects of the future are expected to make possible mining projects that are environmentally energy efficient and environmentally benign. These objectives will require multi-disciplinary teams of engineers and scientists from several fields and the value of physicists in this increasingly complex industry is growing.