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Multidisciplinary Expertise Applied to Underground Coal Mining R and D Projects with Emphasis on Adoption of Lean Automation Techniques

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Abstract: Mining R&D at the University of Wollongong has concentrated on assisting the Industry by developing new techniques enabling mining engineers to exploit the capabilities of other engineering and science disciplines and by assimilating and modifying technologies successfully used in other Industries. Four examples of current multi-disciplinary research projects are reviewed and details of one of these, involving the concept of 'Lean Automation', which has introduced a major change in thinking in other industries, are given. It is shown how Lean Automation has successfully been used in the automotive and aerospace industries by providing maximum flexibility at minimal capital costs, while maintaining the typical automation benefits of increased productivity, quality, safety and control. Lean Automation may provide a solution to long standing coal mining Roadway Development bottlenecks by adapting lightweight automation to the tasks of automated rock drilling/bolting, mesh installation, and other roof support systems.

1 Introduction

Mining is a complex and large business with unique challenges [eg 1, 2, 7]. One of the dangers in any large business is the siloing of expertise. But R&D breakthroughs are often at the intersection of disciplines, and in using the experiences gained by observing other industries. At the University of Wollongong mining research has benefited from applying the skills of other disciplines to mining problems. This is coupled with the transferring of technologies from different industries and integrating them into the mining process. This 'systems integration' approach may help provide solutions for many long-standing production bottlenecks still to be overcome in most underground coal mines. In this paper, four examples are given which draw on harnessing chemical, IT, and engineering skills in mechanical, electrical, mining and mechatronics for the benefit of the mining industry.

The projects described below have all been supported through the Australian Coal Association Research Program (ACARP). This is a very large cooperative research program funded by companies involved in coal mining throughout Australia.

2 Examples

2.1 Liquid Mesh for Strata Control

This project brings skills from Chemists, Geotechnical and Mechatronics Engineering to the mining industry. In the underground coal industry, roof support activities represent a large proportion of the roadway development process. The installation of steel mesh (Figure 1) for roof and rib confinement is one of the main limiting factors in achieving greater production rates using a continuous miner.

The overall aim of this project is to develop and implement a spray on (liquid mesh) polymeric replacement for steel mesh in underground roadway support. The project formally commenced at the beginning of September 2007, and to date has provided polymeric materials with suitable mechanical properties, containing low odour, low irritancy and low toxicity components. The polymer has been identified by Chemists to provide a quick setting coal containment skin which gels and hardens within seconds from application, allowing rock bolts to be installed immediately after application. The mechanical properties which have been tested are: stiffness, tensile strength, elongation, flexibility, and adhesion to rock/coal. All properties have been shown to be comparable to or exceed steel mesh containment characteristics[3].

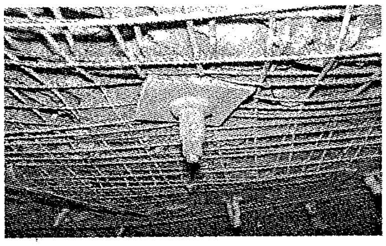


Fig. 1 Steel mesh roof confinement

A comprehensive literature review of flame retardant and anti-static additives has also been conducted, including a review of laboratory-based flammability and anti-static test methods. Experimental trials of potential materials have commenced and a possible spray-on anti-static material is also under investigation.

Geotechnical assessment (by experimentation and numerical modelling) of the role of steel mesh in underground coal mine roadways is also under way. This study is providing a quantitative model for comparing the mechanics of steel mesh under loaded conditions to those experimentally determined with the polymeric materials. The results will guide the selection of the most appropriate polymeric replacement for steel mesh and help determine the optimum geometrical configuration for material application.

Coupled with this investigation, a new mechatronic approach is being considered for the automatic spray application of the polymer at the development face. Automated application removes the operator from the immediate hazardous face and allows higher roof support application rates to be realised. It also provides the possibility of easily varying thickness 'on the fly' as a function of roof conditions to provide additional roof support more cost-effectively.

2.2 The modelling of roadway development to support longwall mining

This project draws on previous work in mining, such as reference [4] as well as expertise developed for conventional manufacturing processes and factories, and aims to exploit this capability to assist in systematically assessing and deriving various options available to miners. Standard procedures and process control for roadway development are continually being reviewed by operators in order to refine potential methods used to increase mining efficiency and drive down production costs. Currently any proposed new work methods or new equipment or new materials handling technologies are generally tested using the actual production process. These trials are often on the critical path of the mining processes that directly affects longwall production and, if miscalculated, can have a significant impact on mine economic viability.

The primary objective of this project is to develop a roadway development simulation model to map and manage the performance of the roadway development required to support longwall operations. A modelling system allows various options to be explored offline to determine how a required development rate, and the systems employed, can be best achieved to support future predicted longwall advance rates, and to assess the effectiveness of any new technology.

This project commenced in March 2008 and interacts with several major manufacturers of mining equipment for the simulation of mine activities using Arena and Delmia V5 simulation software. Both simulation software packages have been extensively used in other manufacturing industries for process design, process control and dynamic statistical monitoring. Figure 2 shows an example of the modeling process of roadway development activities, utilizing 3D CAD static models already developed and made available by heavy machinery manufacturers. The simulation allows the mine operator to quickly determine the optimum mine layout when matching current or future mining machinery to their unique environment. Example simulations currently being developed allow an analysis of the benefits of continuous haulage over batch haulage so that bottlenecks and inefficiencies can quantitatively be determined and analyzed.

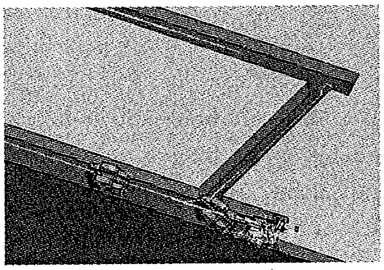


Fig. 2 Simulation of roadway development using Delmia V5

2.3 Auto Bolting and Mesh Handling Project

This project utilises a multi-disciplinary team of engineers experienced in mining engineering, industrial automation and robotics, and in manufacturing. This team is developing a system that can be fitted to a continuous miner platform to fully automate the process of installing Self Drilling Rock Bolts (SDRB) and steel mesh for the primary support of the roof and ribs during roadway development.

This long term project commenced in March 2008 after a 12 month preliminary scoping study which was funded by six mining companies and the University. It will result in the development of an automated support installation system that when taken to full production will reduce the need for manual operations in the immediate face area during roadway development, thereby reducing the risk of contact related and repetitive strain injuries, while potentially reducing the current cycle times for installation of roof and rib bolts and mesh.

This project builds upon the successful development of manually installed self drilling bolts in an earlier Australian Coal Association Research Program (ACARP) project, to enable the full potential of SDRB to be realised in roadway development at longwall mines. The application of SDRB technology with automated consumable handling and insertion systems for automated roof and rib support will significantly reduce primary support installation times. The proposed outcomes from this project are therefore one of the essential requirements before the often stated '15Mtpa' goal can be achieved by the Industry.

An important component of the automated systems will be the design of cassettes and magazines and transportation systems which allow for the preloading of roof support materials, including bolts, mesh and all associated components, into magazines that can be safely transported and conveniently loaded onto the continuous miner for automatic dispensing by the automated fixing systems. Attention is being paid to ensuring that the automated system can deal with alternative SDRB, or alternative skin reinforcement systems which may become available in the future.

Currently there are no automated SDRB systems commercially available for use in underground coal mining applications, although manual installation of SDRB has been successfully demonstrated as part of another current ACARP funded project. This project aims to build upon these recent advances and adapt the SDRB technology for application on continuous miners. This may necessitate significant redesign of existing Continuous Miner mounted bolting machines.

The project will also build upon similar automated systems within the tunnelling and mining sectors and will seek to use the latest advances in automation and robotic technology to deal with the specific challenges of the underground coalmine environment. Some of these challenges include:

(1) using sensors, actuators, manipulators and controllers that are compatible with gaseous, dusty and/or wet conditions and are Intrinsically Safe.

(2) developing a cost-effective system within the confined space limitations of the continuous miner and the immediate area surrounding each drilling machine.

(3) creating a robust system whose component design ensures machine reliability and longevity.

(4) designing for easy operation and maintenance.

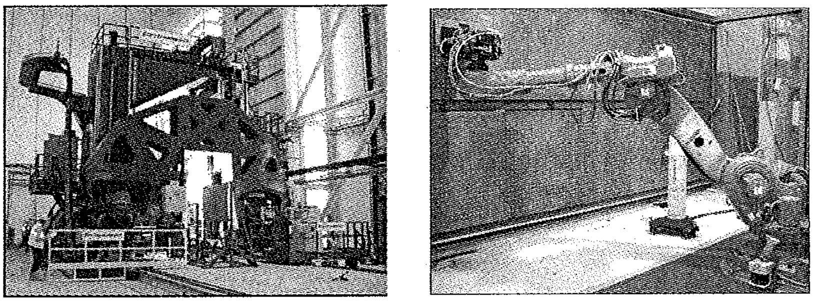
In order to accelerate the mining industry's use of appropriate technology, this project aims to utilise key enabling technologies already successfully developed for other industries. This not only includes other parallel sectors such as hard rock mining, but also manufacturing sectors such as the aerospace and automotive industries where recent innovation has created step changes in production efficiency and operator safety.

2.4 Lean Automation for Mining

Lean Automation uses standard light weight reconfigurable robotics, simplified material delivery systems and advanced sensing in place of more traditional rigid and dedicated automation. For many industries this has played a significant role in delivering both the efficiencies of automation as well as the advantages of relatively low cost and high flexibility infrastructure. The concept of Lean Automation using flexible equipment requires a shift in thought away from traditional dedicated and purpose built automated machinery, to provide quick adaptation to variable work environments and easy retrofitting of existing plant equipment.

An example of Lean Automation in action can be seen in Figure 3 where the traditional heavy rigid machinery capable of high accuracy drilling is replaced with a much lower cost and lighter weight robotic facility. In the latter system, the same (and in most cases superior) accuracy can be achieved by combining advanced sensors and intelligent control into an integrated system[5]. The new process allows for quick adaptation to variable work environments and easy retrofitting of existing plant.

In the coal mining industry, heavy machinery operation such as coal cutting, clearing and conveying represent a fraction of the overall mine development oper-



(a) Traditional rigid machinery; (b) Lean Automation alternative
Fig. 3 Automated drilling using:

ation. Although those processes require robust rigid systems, other operations, such as materials handling, primary and secondary support installation and panel services advancement, often use the same restrictive heavy miner operated equipment and hydraulic services.

For the University of Wollongong's automation projects (Liquid Mesh Polymeric Spray on Liner and Auto-bolting and Mesh Handling) Lean Automation offers a new way to achieve coal face support operations. The advantages of a stand alone and reconfigurable automation system allows for easy retrofitting of a range of existing continuous miners throughout the industry.

Figure 4 shows one possible lean automation configuration on a man-less Continuous Miner platform. Using a programmable manipulator and flexible robot attachment, multiple tasks can be realised with the same device. These tasks may include self drilling rock bolt, washer and plate insertion followed by mesh manipulation or alternative spray on polymeric liner application. The most notable advantage of this system is the minimal modification to the Continuous Miners required.

For these systems to function independently, sensing is usually a key attribute to the system's success. Advances in metrology feedback used extensively in the aerospace industry, offer modern solutions to position and orientation awareness for assisting automatic machine control[6].

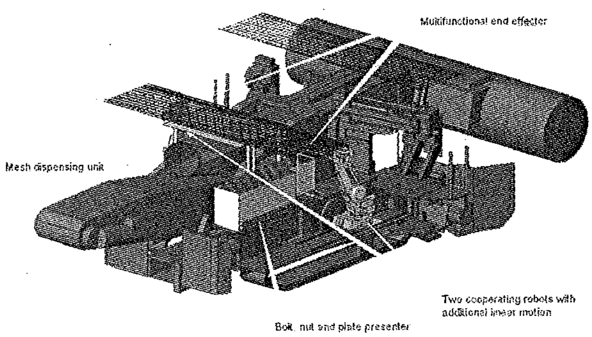


Fig. 4 Lean Automation in the roadway development process

3 Conclusions

This paper gives four examples of R&D projects showing how Research and Development in the underground coal mining industry can benefit both from other disciplines, and from practices in other industries.

One of the major aims of the industry is to achieve a production rate of 15 Million Tonnes per annum from longwalls. A significant barrier to this ambitious aim is not the longwall itself but the roadway development to support the longwall. Major improvements in technology and work practices will be required in roadway development for the future. The review of the projects above describes the way in which other disciplines, and experiences of major change in other industries, such as lean automation, are being exploited in current research projects in the hope that these will provide a way to assist underground coal mining.

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