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Longwall automation: Delivering enabling technology to achieve safer and more productive underground mining

Ralston Jonathon C. *, Reid David C., Dunn Mark T., Hainsworth David W.

Coal Mining Research Program, CSIRO Energy, Pullenvale, Q 4069, Australia

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ABSTRACT

The ongoing need to deliver improved safety, productivity and environmental benefit in coal mining presents an open challenge as well as a powerful incentive to develop new and improved solutions. This paper assesses the critical role that enabling technologies have played in the delivery of remote and automated capability for longwall mining. A brief historical account is given to highlight key technical contributions which have influenced the direction and development of present-day longwall technology. The current state of longwall automation is discussed with particular attention drawn to the technologies that enable automated capability. Outcomes are presented from an independently conducted case study that assessed the impact that CSIRO's LASC longwall automation research has made to the longwall mining industry in Australia. Importantly, this study reveals how uptake of this innovative technology has significantly benefitted coal mine productivity, improved working conditions for personnel and enhanced environmental outcomes. These benefits have been widely adopted with CSIRO automation technology being used in 60 per cent of all Australian underground operations. International deployment of the technology is also emerging. The paper concludes with future challenges and opportunities to highlight the ongoing scope for longwall automation research and development.

1. Introduction

1.1. CSIRO mining strategy and rationale

Industrial Research Organisation (CSIRO) undertakes mission-directed research to promote transformational change in the Australian mining and resource ecosystems. The vision is to secure a clean energy future in order to sustain long term benefits across environmental, economic and societal sectors. The fundamental approach has been to collaborate with industry, research organisations and government to create cost-competitive, low-emission energy technologies. A vital component of this strategy has been the development of remote and automated mining technologies to achieve safer, more productive and more environmentally sustainable coal mining systems. Coal accounts for around 24% of employment and 27% of total revenue for the Australian mining sector. Longwall coal mining, in particular, accounts for around 90% of Australia's total underground coal production and thus represents a major interest area for innovative research and development.

1.2. Longwall coal mining process

Longwall coal mining is a full extraction underground mining method that involves the removal of coal in large blocks or panels using a mechanised shearer. The coal panel is typically 200–450 m wide and can be up to five kilometres in length. The mechanical shearer is mounted on a shearer pan and rails which guide the shearer as it moves back and forth along the coal face. Coal cut from the longwall face by the shearer is removed by an Armoured Face Conveyor (AFC) that transports coal to the adjoining gateroad for conveyance to the surface.

The roof over the working area is supported by hydraulic shields that are advanced towards the freshly cut face according to a well-defined motion configuration. As the roof support system advances into the coal panel, the roof behind the shields is no longer supported and is thus allowed to collapse into the void (goaf) behind the shields. For reference, a representation of a small portion of a longwall operation and shearer is shown in Fig. 1. The coal seam is indicated by the hatched layer between the underlying and overlying strata.

* Corresponding author. Tel.: +61 7 33274702.
E-mail address: jonathon.ralston@csiro.au (J.C. Ralston).

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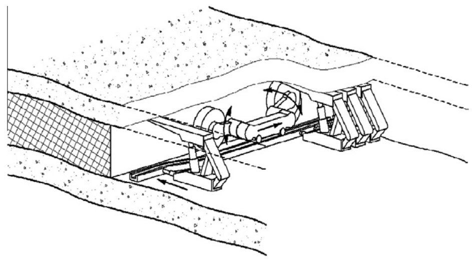

Fig. 1. Cut-away view of the underground longwall mining process (the shearer is in centre view, mechanised roof supports to the left and right, and embedded in coal (hatched) and host strata (dots)).

1.3. Need for improvement

Despite the high potential productivity associated with longwall mining, the operational environment presents many hazards to personnel, including proximity to machinery, hydraulic and electrical power, roof falls and exposure to explosive mine gases and dust. Miners have for decades been required to work in this hazardous environment to manually control the equipment at close range in an attempt to achieve an efficient mining operation. However, ensuring the optimal orientation of the longwall face and equipment is critical: a need to stop production periodically to carry out manual adjustments reduces operating machine time and thus is a lost opportunity. Further, extraction needs to be maintained in the coal seam: failure to correctly position the shearer drums can lead to loss of coal recovery and/or unwanted spoil (rock) diluting the coal product. Either of these events reduces the efficiency of the mining process. Thus the complexity of manually operating equipment of this scale has led to suboptimal product recovery and potential health and safety concerns for personnel.

Underground mining operations have consistently expressed the view that the longwall is the prime profit centre. Any automation effort therefore needs to achieve a high level of production consistency and reduce the exposure of personnel to respirable dust and other hazards. This safety aspect of automation is important as most high production faces often find statutory standards difficult to achieve, even with advanced dust control techniques. The industry recognised that this was increasingly unacceptable and unsustainable in the long term and sought answers to these problems.

Mining automation technology demonstrates significant potential to provide meaningful solutions to this problem by facilitating more accurate mining methods, incorporating sensing to optimally control equipment, and increasing personnel safety through remote process operation. However many previous attempts at achieving longwall automation were not sustainable, lacking the necessary degree of technology readiness [1].

CSIRO has successfully developed ways to help automate longwall mining through the introduction of innovative enabling technologies. Elements of these technologies, known in the industry as Longwall Automation Steering Committee (LASC), have been taken up by all major longwall Original Equipment Manufacturers (OEMs) under technology licensing agreements with CSIRO. Each OEM has incorporated the LASC open intercommunication standards into their proprietary control system architecture and shearer manufacturers have integrated the core automation hardware systems into their equipment. This paper details these innovative technology developments and describes their practical impact on the underground coal mining industry.

1.4. Paper overview

The paper begins with a brief historical review of the automation-centric initiatives which played an important role in the development of longwall automation capability. The drivers and outcomes of these efforts are then described. An overview of the state of current automation research and development is given with a specific focus on innovation and impacts associated with LASC automation technology for Australian longwall operations. A case study is given to highlight the technical and industrial impacts associated with the introduction of LASC automation technology. Finally, new and emerging trends are presented to highlight both the ongoing challenges as well as opportunities that exist to support safer and more productive underground mining.

2. Longwall automation history

This section overviews the major historical drivers of, and developments towards, present-day longwall automation technology. Whilst many initiatives did not manage to fully realise their overall aim or scope, collectively these efforts proved to positively influence both mining culture and industry confidence in the use of technology for longwall automation. This historical background provides an ideal context to describe the automation research and development undertaken by CSIRO to improve the safety and productivity of longwall mining.

Since the 1960s there have been a number of attempts worldwide to develop longwall automation systems [2,3]. These had been largely unsuccessful because it had not been possible to accurately and reliably measure the positions in space of the principal elements of the longwall. This information is fundamental to automation because unless the current location of equipment is known it is impossible to command the equipment to travel on a desired path. The CSIRO research team realised that if the position of the longwall shearer could be measured continuously in three-dimensions, the path the shearer takes in the mining process would then enable the positions of all the individual powered supports and, moreover, the track of the mined roof and floor, to be calculated. This was a breakthrough in the evolution of mining automation.

2.1. Remotely operated longwall face (ROLF)

The drive to develop remote and automated capabilities for longwall operations can be traced back to as early as the 1950s in the British underground coal industry. Here, interestingly, the primary driver for automation was not safety or efficiency per se but rather as a strategy to support the rationalisation of wage structures for workers in the coal industry. At the time, mining was largely a pick-and-shovel process, but mechanisation was being rapidly (but not uniformly) introduced. This change was leading to wide disparities in task equity and remuneration for mining personnel [2,4].

Ongoing negotiations involving the British Government, the National Coal Board and Unions eventually led to a National Agreement in 1955 based primarily on the concept of a *Remotely Operated Longwall Face*, colloquially referred to as 'ROLF' [2]. It was thought that if such a system could be developed, then task and wage equity would be immediately achieved as it would be machines, not men, fundamentally dictating performance. By 1960, the notion of a "manless face" was even being discussed, together with the tantalising prospect of coal production becoming a simple "push-button operation". The National Coal Board was charged to undertake the research into the development of a ROLF system. Pioneering experiments were conducted in the early 1960s in an attempt to develop the ROLF capability.

After a number of attempts at technology development, it was clear that ROLF simply did not have the level of maturity and performance necessary for production conditions. The lack of suitable sensing, computation, and remote-control technologies also