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DESIGN FOR AUTOMATED SELF ADVANCING MONORAIL

Luke Meers and Stephen van Duin

ABSTRACT: This paper discusses the need for the automated installation of monorail sections which are used for the support of services and ventilation ducting to the continuous miner during roadway development in underground coal mining. The paper analyses the current state of development monorail technology and identifies how self extending monorails would complement new technologies emerging in automated roadway development, resulting in increased advance rates and improved safety. The constraints and challenges in designing for an automated solution are identified and discussed.

INTRODUCTION

Research and development into the automation of the roadway development process in underground coal mining is well under way. The Australian Coal Association Research Program (ACARP) has developed a strategy for a high capacity roadway development system. This includes a key goal known as CM2010, aiming to achieve development rates of 10 m advance per operating hour (MPOH), 20 h per day (Gibson, 2010). Part of this planning strategy has been the identification of key enabling technologies required if the development rate goals can be realised. As a result, the industry has funded research addressing the automated handling of bolts, mesh and washers, technology for self steering miners as well as polymer roof support technologies. Upon implementation, these new technologies will mark significant steps forward in the roadway development process; improving advance rates and eliminating the need for operators at the roadway coalface.

A critical element of roadway development is the efficient utilisation of resources and an effective supply and handling mechanism for face services. The interaction between these activities affects the overall performance of roadway development. Furthermore, high cutting rates as envisioned create smaller windows of opportunity to complete necessary activities such as the installation of support infrastructure and extension of face services. The automation of monorail installation would improve the development process by:

- eliminating the need for personnel to manually advance the monorail, thereby reducing heavy manual handling and exposure to 'no-go' areas;
- integrating the automation of the monorail with other automation activities being developed for the continuous miner; and
- increasing the installation rate of the monorail inline with a high capacity continuous miner development system.

An industry analysis has been performed to assess the current state of monorail technology. Monorail technology has been utilised in the mining industry since the late 19th Century (Oguz and Stefanko, 1971). Whilst there is much evidence of monorail technology assisting in production safety and efficiency (Coppins, 2008), what is absent is any literature detailing innovation in the automated installation of monorail, either in the mining or any other industry. Currently, monorails are used in underground coal and ore mining as a means of transport (Guse and Weibezahn, 1997), batch haulage (SMT Scharf EMTS brochure, 2011; Anon, 2011) and as a means of managing services to the longwall face (ACARP, 2011).

Development monorail systems are less common. In Australia, there are two main varieties of systems available tubular section monorail; and I-beam monorail. The tube section monorail is lighter (approx 15 kg per 2 m rail), lower in cost and is a simpler system capable of carrying light weight services such as air, water, power cables and ventilation ducting (Appleby, 2011).

The I-beam system can support higher loading than the tubular profiles, allowing it to carry heavier equipment such as pump and fan units (Macquarie Manufacturing, 2011). Critically, it is also designed

to remain in the belt road after development to support services to the longwall face. Figure 1 shows a typical layout for the I-beam monorail system including multiple drive units.

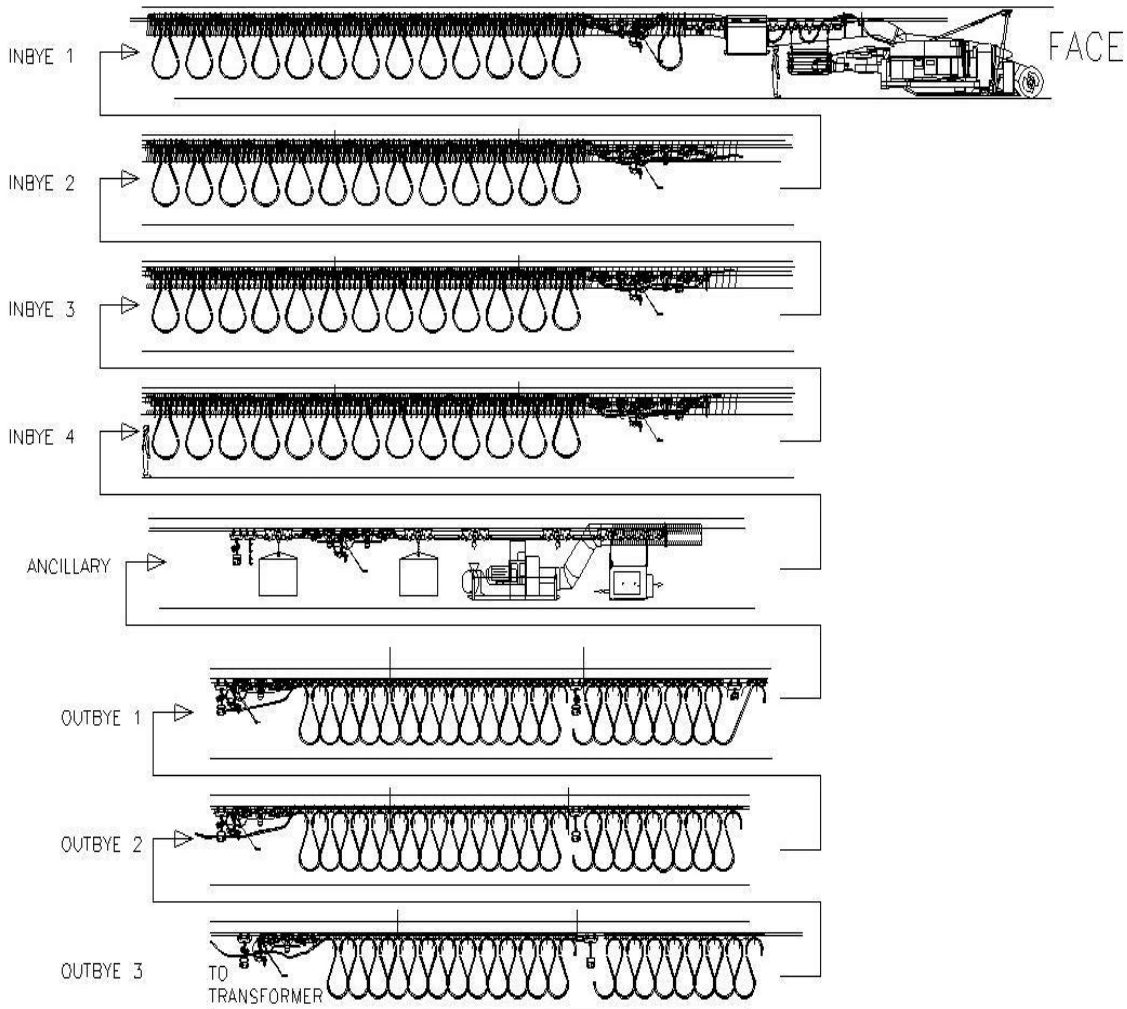


Figure 1 - Development monorail schematic diagram (Coppins, 2008)

Roadway development without monorail assistance requires the manual fitting of vent tubes and support infrastructure to the roof support at a rate matching that of development. Installation of a conventional monorail system eliminates the need for the manual handling of vent tubes and face services, reducing injuries (Shales, 2010), but replaces this with the manual handling of the typically 25-30 kg rails in the hazardous zones to maintain support to the coal cutting process. Issues that have been related to the manual handling include:

- Potential for back or trunk strain injuries, cuts, abrasions, contusions and crush injuries sustained while transporting, handling and restocking monorail sections and advancing services, particularly in mines where roadways are developed at heights in excess of 3 m;
- Exposure of personnel to the immediate face which is prone to outbursts, dust, noise and collapsing coal;
- Exposure of personnel to interacting processes such as coal cutting, coal wheeling and services advancement.

Manual rail installation becomes more onerous as mining heights increase, with operators facing increasing ergonomic risk as they lift monorail segments into place at height. The rates of development targeted by the industry, further compounds these issues. Furthermore, the work area currently utilised to install and extend monorail segments is likely to be required for functions of the automated continuous miner, necessitating these regions be designated "no-go" areas during automated operation of the bolt

and mesh handling systems - hence an alternative approach to monorail advancement is required. A self advancing, automated monorail eliminates the need for manual handling of the rails from the miner, effectively removing the three key risk areas noted above.

A key driver for self installing monorail technology is the need to integrate the supply of services and ventilation to the miner with other automated roadway development equipment. The automated handling of roof support consumables on the miner (Van Duin, *et al.*, 2011) utilises the deck space traditionally used to manually install the monorail. Additionally, the automated tasks involve moving equipment which would likely create "no go" zones, effectively eliminating any space on the miner from which rail could be manually installed.

Figure 2 shows one example of a timeline for the automated tasks used in the handling of the strata support consumables over a one metre cycle.

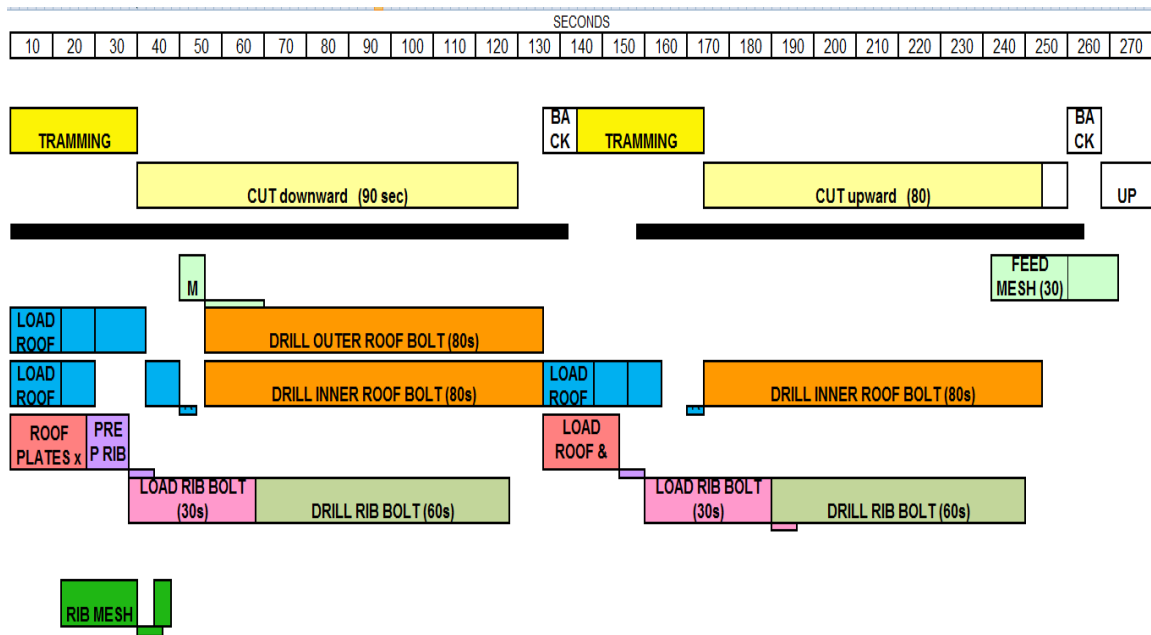


Figure 2 - Automated continuous miner, Task timeline (Van Duin, 2011)

The timeline illustrates that over the five minute cycle there is no time available where personnel would manually install a monorail beam. Manual installation of rail would require the full isolation of all mesh and bolt handling processes on the miner in order to allow the operators to gain access to the machine. The industry is pushing towards faster roadway advance rates and as such the interruption of the already critical bolting cycle is not a feasible option. However, an automated installation procedure could be designed to integrate with the process cycle of the miner allowing the cycle shown to continue uninterrupted and thus achieve maximum advance rates.

DESIGN FOR AUTOMATION

An automated self-installing monorail system requires the development of several key mechanical components. When considering the design of existing monorail sections and ancillary components, the following actions/movements, or equivalent would be required:

- Delivery of the rail to the rear of the continuous miner (one 2 m rail every 12 mins in a 10 MPOH system);
- Transfer of rail from the delivery system onto a rail handling device;
- Manipulation of the rail into the installed position;
- Connection of the rail to the previously installed rail;
- Manipulation of the attachment between the rail and roof support;
- Adjustment and locking of a height adjustable mechanism between the roof and rail, and

- Return to home positions.

Design constraints

The design of a self advancing, automated monorail system to integrate with an automated continuous miner inevitably involves the consideration of a large range of design constraints and challenges, these include:

Installation location: The strict requirements in most underground coal mines for ventilation require the ducting to be run up as close to the face as possible. Most modern continuous miners include sections of integrated ducting. The monorail, supporting the vent tube must therefore be installed inbye of the connection between vent tube and the onboard miner ducting, effectively alongside the rear of the miner.

Available space: The rail handling equipment must fit in the envelope between the miner and the rib whilst allowing for variation in rib conditions and the position of the miner. This allows for equipment no wider than 500 mm. The rail handling equipment must also be located and dimensioned such that there is space for it to move 2 m outbye relative to the miner before the space is available for the subsequent rail piece to be attached.

Installation time: The installation process must also be performed at the appropriate time to avoid clashes with the automated miner functions such as, movements of mesh and bolts. This would most likely be during the drilling phase because the miner is stationary and movement of consumables is restricted. This also necessitates data communication and logic control integration between the monorail system and the continuous miner.

Volumes: At 10 MPOH, one 2 m rail is required every 12 min. This involves not only installation but also delivery from outbye storage. At 30 kg per rail, a 10 h shift would require 1800 kg of stored rails.

Roof support: Current practice for I-beam monorail generally involves hanging from a dedicated roof bolt. If 10 MPOH rates are to be achieved, this is not likely to be possible due to the extra time required for dedicated bolt installation, thus requiring the system to be attached to primary roof support.

Roof conditions: The system must be able to compensate for uneven roof contours. Some automated adjustment must be possible to allow the rail to run smoothly despite roof conditions.

Adverse conditions: dust, water ingress and rock falls necessitate that any design must be sufficiently robust to cope with the environment.

Approved materials: the system must comply with current standards for materials, control equipment and actuation devices and communications.

Cut throughs: In order to achieve a fully automated process, handling and installation of curved rails for cut throughs is required. This may also necessitate the ability to attach intermediate support along the curved rail to reduce offset loadings.

Compliance: The system must incorporate enough movement and adjustment to tolerate the dynamic loads which will occur during the tramming of the monorail based equipment. This includes sideways tilt and vertical give.

These constraints highlight the range of technical challenges which must be addressed to achieve a feasible self advancing monorail. There are several key features that are likely to be incorporated into the design.

Outer roof bolt placement will be critical along the monorail centreline. Whilst this is not physically part of the monorail system hardware, the equipment will be required to locate and attach to the roof support. Thus, a control system on the miner which can accurately reproduce the spacing of bolts in the roadway is necessary. Additionally, the control system of the continuous miner and the monorail will require integrated logic control in order to ensure correct positioning and timing is achieved.

Height control could be achieved via adjustment of the mechanism which attaches from the rail to the roof support. Current manual monorail systems rely on a length of chain being hung by the appropriate

link, but a more rigid mechanism would be necessary to enable automated handling. The height adjustment system must also lock in place, but allow enough compliance for rail alignment and dynamic loading as described previously.

The connections between rails would ideally be simplified from current systems. This link would not require actuation but would lock in place as the rail is inserted. This connection must also be capable of supporting the heavy loads of the multiple tonne trolleys that will be mounted on the rails. Vertical and horizontal angular compliance is also required, for slight changes in heading or height of the roadway.

At a development rate of 10 MPOH storage of rails onboard the miner, or even below the vent ducting, is unlikely. As such, the transfer of individual rails every two metres from a dedicated delivery system integrated with the delivery of the consumables to the miner would be most suitable.

This research will endeavour to progress with concept design work which incorporates the constraints and design criteria mentioned here, working towards the development of a complete concept for an automated, self advancing monorail system.

CONCLUSIONS

Monorail technology is common in many forms of mining, but to date there have not been any systems developed in which the installation procedure is automated. As advance rates in roadway development increase, the manual handling of services to the face and the manual handling of monorail beams themselves, becomes increasingly difficult. Automating the installation of monorail sections, creating a self advancing system, alleviates the safety problems of handling rails manually near the coal face and complements other areas of roadway automation currently being developed. However, by highlighting the issues that have led to the need for an automated approach, this paper has also identified the challenges relating to the design of an automated self-advancing monorail system. Now these have been categorised, the process for automated design can begin.

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