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[pages 102 – 108]

ANALYSIS OF THE MACQUARIE MONORAIL SYSTEM IN DEVELOPMENT OF GATE ROADS AT MANDALONG MINE

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ABSTRACT: Gate road development lies on the critical path in the longwall production process. To address this issue industry has invested substantial resources in developing technologies such as continuous haulage and bolting cycle automation. There has been limited focus on improvement of ancillary development processes and technologies such as the provision of face and panel services and the panel advance process.

A monorail system has been in use for some years at Mandalong Mine near Lake Macquarie in N.S.W. The Macquarie Monorail system is an integrated gate road development services unit and differs from many existing monorail units employed in underground operations as it is designed to manage all face services while as well as carrying heavy panel plant such as the section load centre and auxiliary fan.

Use of the system at the Mandalong Mine has resulted in increased productivity and safety performance during gate road development. Reductions in service move and operating delay times of 32% and 25% were observed respectively along with a 70% reduction in manual handling injuries.

The system is not without its disadvantages chief being significant manual handling is necessary in the erection of the relatively heavy monorail structure and replacement of the flexible ventilation ducting. Despite these minor limitations of the system, the overall safety and productivity performance of gate road development was found to be superior to conventional development units.

INTRODUCTION

As longwall productivity has increased over the years, it has not been matched by gate road development with advance rates often being insufficient thereby inhibiting the potential rates of longwall retreat (Mitchell, 2009).

The majority of research undertaken to address this issue has focused on the development of capital-intensive technological solutions such as automated bolting and continuous haulage systems (Gordon, *et al*., 2008). This approach has largely failed to recognise the potential benefits that might be achieved by eliminating or reducing process delays in roadway development such as provision of services, flit times and panel advances.

In addition, while there have been significant improvements to ergonomics within the mining industry in recent years, there is still considerable scope to reduce and in some cases eliminate manual handling tasks thereby contributing to improvements in operator safety. Manual handling injuries are one of the most common causes of significant injury in underground mining operations in Australia (Burgess-Limerick and Steiner, 2007).

THE MACQUARIE MONORAIL SYSTEM

Overview and description

The Macquarie Monorail (MM) is a roof mounted, integrated development services system that aids in the management and mobility of face services and heavy equipment. The system was first employed at Centennial Coal's Newstan Colliery operations in 2006. It was subsequently relocated to the Mandalong operation in 2009.

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One of the primary design objectives of monorail systems is management of face services such as cables and hoses. In the case of the MM system these services include electrical power, air, water, return water and ventilation as illustrated in Figure 1.

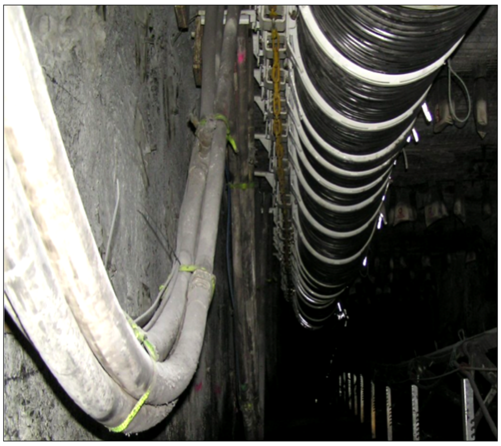

Figure 1 - The conventional services handled by the Macquarie Monorail system

An added feature of the MM system is its ability to also handle the section load centre as well as auxiliary fan as illustrated in Figure 2 together with other ancillary equipment including the electric pump starter and fire depots. This eliminates the need to disconnect these services and relocate the heavy equipment during the process of each panel advance. Hence reducing, if not eliminating, the risk of injuries associated with manual handling of services as well as the time to complete each panel advance.

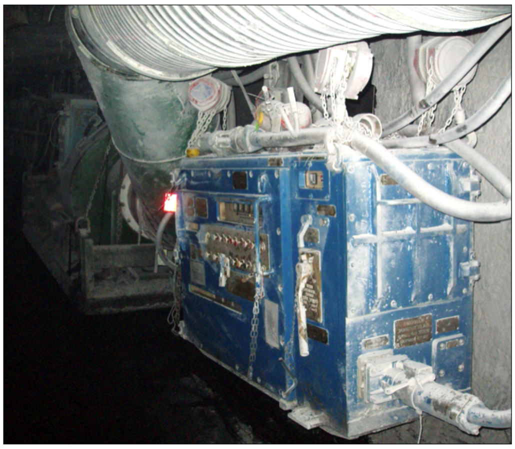

Figure 2 - Additional outbye services handled by the Macquarie Monorail including the load centre and fan

The entire system is mobilised by a series of manually operated pneumatic traction drives that allow the system and its integrated services to be advanced and retracted as required.

System configuration in panel development

A typical layout in a gate road development employing the MM system is shown in Figure 3.

The MM system is currently configured to enable gate road development of up to three pillar lengths in each development cycle before a move of the panel transformer is required. Typically disconnection, relocation and reconnection of services is not required within each cycle.

On completion of a panel transformer move, the section load centre is reconnected to the transformer through the Macquarie Monorail. The other services including compressed air and water are separately connected to service outlets. This arrangement allows extension of services and the high-tension cable to occur independently of the pillar production cycle.

Once development of three pillars is complete the transformer is relocated and reconnected to the monorail as the next transformer move cycle begins.

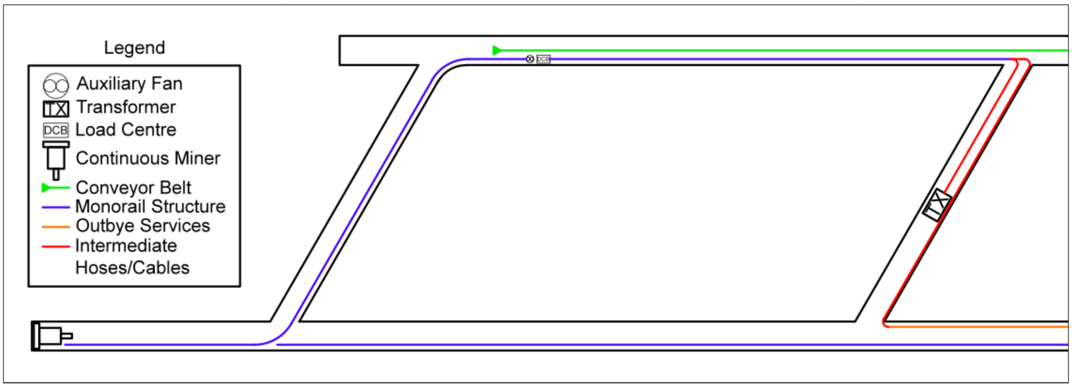

Figure 3 - Panel configuration using a Macquarie Monorail system

ANALYSIS OF PRODUCTIVITY PERFORMANCE

A study was undertaken to compare the performance of the MM system against conventional development without the use of a monorail system in similar conditions. The investigation centred on two adjoining gate roads designated as panels MG11 and MG12 that were developed by conventional methods and the MM system respectively. The study spanned development of 26 pillars in each case which equated to approximately 7 km of development and a similar number of panel advance cycles.

Overall it was found development undertaken with the MM system was completed in 303 days which was 26 fewer days than with the conventional method. This equates to an increase in production rate of approximately 8% or on average an additional 2.16 m advance in every 24 h period.

Key delay groups

An analysis of the reported delays in each of the two development roadways was undertaken. As is shown in Figure 4 there was an appreciable reduction in the length of many of the different categories of delays with the MM system chief among these being service moves or panel advances delays and operating delays. However there were slight increases in the delay categories designated as production and plant maintenance.

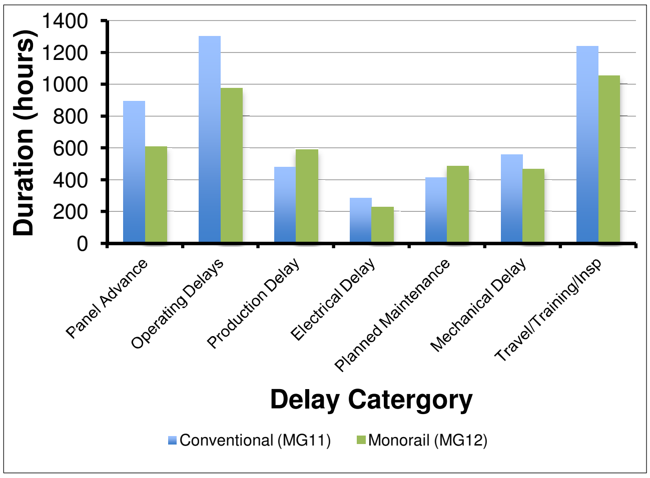

Figure 4 - A comparison of key gate road delay groups

One of the greatest improvements was the reduction in panel advance delays where use of the MM system resulted in a 32% reduction representing 285 h. This result can be directly attributed to the design of the monorail system and management of face services.

Of particular note was completion of a panel advance in less than ten hours which was achieved on five occasions as is indicated in Figure 5. In one particular 12 h shift the development crew not only completed the whole panel advance but went on to cut 10 m of coal. Also worthy of note was the gradual improvement in the whole process of a panel advance as evident by the decline in the moving average of the duration time shown in Figure 5.

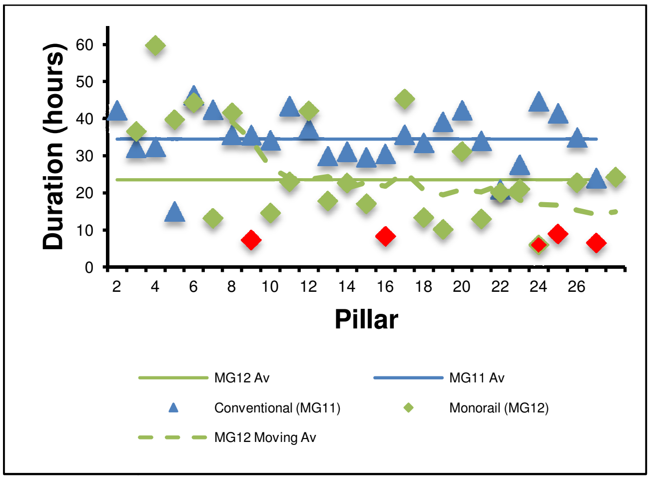

Figure 5 - Individual and average panel advance durations

The reduction in operating delays by 327 h represents a 25% improvement. This was achieved through the simplification of the flitting process and elimination of the need to install rigid ventilation ducting. A slight reduction in electrical delays was also observed due to the reduction in incidence of damage to electrical cables.

Production delays however increased by 100 h or 22%. This increase was primarily due to replacement and cleaning of the flexible ventilation ducting. The ventilation arrangement in the MM system includes a 'drop box' located immediately behind the continuous miner. This 'drop box' was limited in its ability to filter dust and moisture from the ventilation air. This caused a build-up of fines in the flexible ducting which reduced the ventilation efficiency and necessitated frequent downtime for cleaning and/or replacement. This meant an increase in risk associated with manual handling with change-out of components in the ventilation system.

As the monorail system added to the inventory of equipment in gate road development, the call on planned maintenance increased by 75 h.

ANALYSIS OF SAFETY PERFORMANCE

A comparison between conventional and MM system development showed there were 37% fewer incidents and injuries in using the monorail system. The reduction in injuries alone was found to be 31%. Significantly no instances of medically treated injuries or suitable duties injuries were recorded and there was a reduction in the severity of most injuries.

Of particular note was the reduction in manual handling Injuries by 70% as seen in Figure 6.

Manual handling injuries

Within the category of manual mandling Injuries a reduction in all causes of injury was found. Perhaps the most significant of which was the complete elimination of injuries associated with handling of the miner cable, as shown in Figure 7. As these injuries can often be severe, typically resulting in a suitable duties or lost time injury incident, this is considered as an excellent result by management. It was also found that injuries related to ventilation tube installation were reduced owing to the flexible ventilation system incorporated in the MM system.

It should also be noted that a 'light' monorail unit was utilised within the conventional gate road unit, solely for the management of the 'elephant's trunk' between the continuous miner and the rigid ducting. Some manual handling injuries were attributable to the use of that system, more so than with the MM system.

This is significance as the structure on which the MM is mounted is far more substantial than the 'light' monorail system where each segment of monorail has a mass of 30 kg.

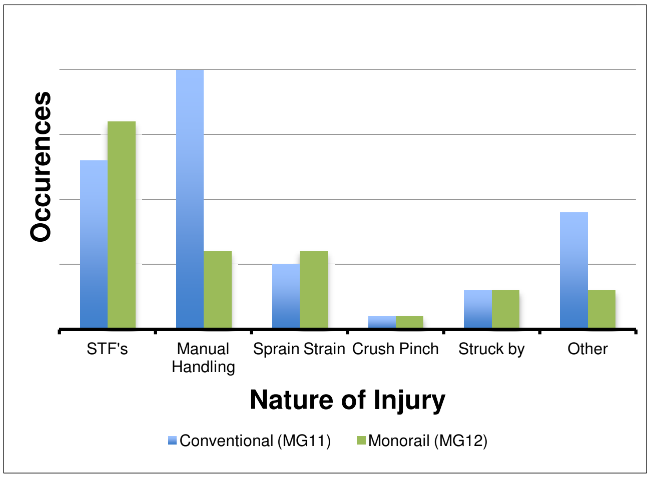

Figure 6 - A comparison of recorded injuries by type

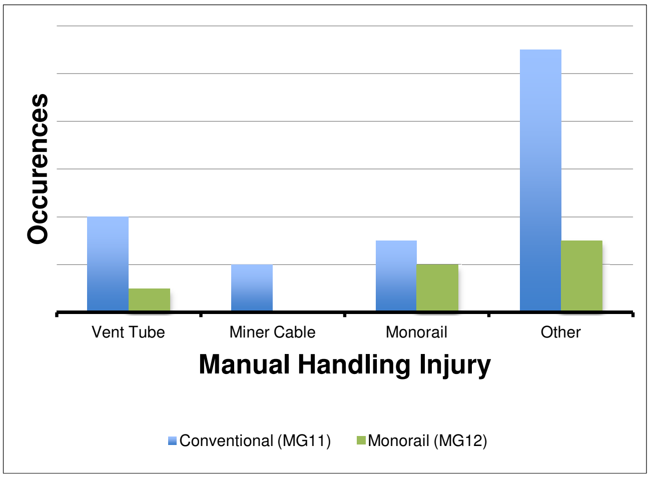

Figure 7 - A comparison of Manual Handling Injury causes

Despite the actual lower number of monorail structure-related injuries recorded with the MM system there was a greater potential risk to operators in the repetitive lifting of each rail segment due to its weight and shape. As a result, a lighter weight structure should be developed to mitigate this risk to operators.

PROCESS IMPROVEMENT

In order to determine the areas where improvements could be made in the performance of the MM system, a systematic analysis of the transformer cycle process was undertaken. It was found that the MM system underperformed during the hole-through process between headings, as shown in Figure 8. It was identified that this poor performance may have been due to the lack of a formalised procedure and sequence for the process. To address this, two sequence plans were developed in consultation with operators and staff these were then trialled to determine the optimum method of holing-through. However, due to panel relocation, the results of these sequences have yet to be finalised.

It was also found that operators frequently encountered difficulty in the installation of curved monorail structure during the hole-through process as it relied on judgement of the operators in the installation of the curved structure to join with already installed structure. If operators installed any one of the curved sections of structure in an incorrect location or orientation then the structure would not join to the existing structure as shown in Figure 9. To address this a lightweight 'template' of the curved monorail structure was eventually developed to aid operators in identifying the correct installation location while also reducing the manual handling risk to the operator.

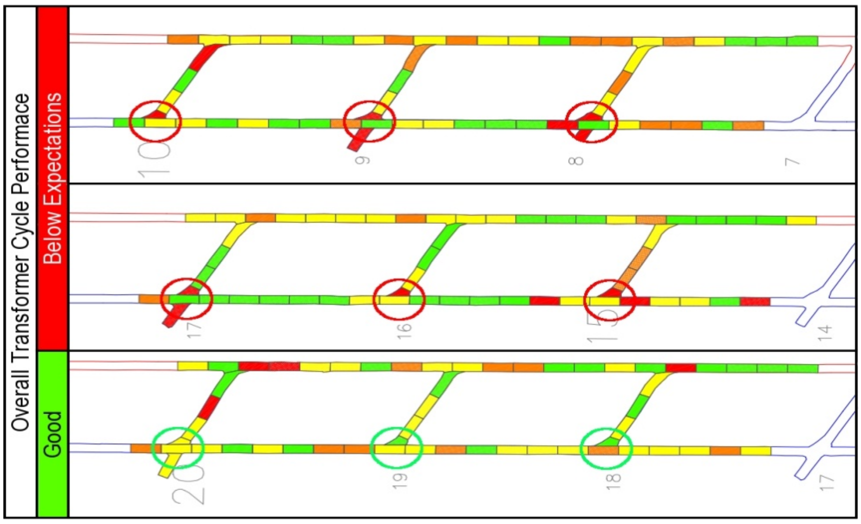

Figure 8 - Transformer cycle productivity analysis highlighting poor hole through performance

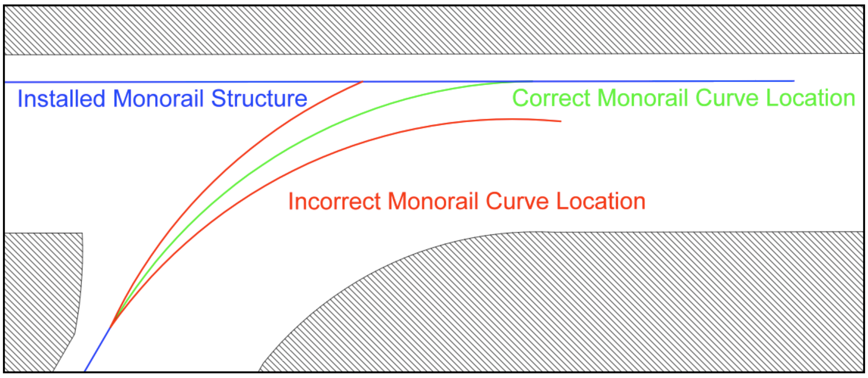

Figure 9 - Examples of correct and incorrect monorail curve structure installation locations

FURTHER OBSERVATIONS

Ventilation efficiency

The in-bye air filtration system unit used in the ventilation system resulted in build-up of fines in the exhaust ducting. While this issue was manageable at the Mandalong Mine, it is likely to be of greater concern in mining operations located in warmer climates where heat management at the development face can be more challenging. In these situations it is possible that poor ventilation performance would not only affect operator safety but also reduce productivity.

Research is currently underway sponsored by both mine management and equipment manufacturer to find an adequate solution to the issue.

Flexibility

As identified in the transformer cycle analysis, without proper process management, performance of the monorail system can decline when changing drivage direction. This is an issue that can be mitigated through effective management.

This study was limited to investigation of development of a two heading gate road with a single continuous miner. While a similar system has been developed for multiple heading development panel and a version of the system is currently being investigated for use in multiple miner panels, effective application of the technology in these circumstances is yet to be studied.

Structure weight

[pages 102 – 108]

The mass of each segment of monorail structure is approximately 30 kg. In addition to the potential for serious crush-pinch injuries, the repetitive nature of structure installation increases the potential long-term health risk to operators. It is recommended that a rigid, lightweight alternative to the existing monorail structure be developed to further improve operator safety.

CONCLUSIONS

Overall gate road development using the Macquarie Monorail system was found to be superior in performance to conventional gate road development in terms of both productivity and safety performance at Mandalong Mine.

Despite this positive result the system is not without its flaws, and there exists potential for further performance improvements with a focus on system design and management. As such, it is recommended that systematic and targeted continual improvement of the system be continued to further facilitate the successful application of this technology.

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