Automation in longwall coal mining-a review

Abstract

Coal is one of the most important fossil fuels which are available abundantly around the world and meets a major part of the energy needs. Coal can be extracted in blocks by using longwall coal mining using a mechanized shearer. From the last century, the automation in industry has become one of the powerful forces of the production. This paper highlights the development and improvement of automation in longwall coal mining. This paper aims at reviewing the stage wise development of automation in longwall coal mining. The study also discusses the difficulties involved in automation integration to the older production system and also highlights the keys features such as remote-controlled monitoring operation in longwall coal mining. A brief review of major longwall coal mining automation challenges and several changes which has undergone from last 60 years has been presented in this study.

Keywords: fossil fuels, remote-controlled monitoring, coal, mechanized shearer

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Introduction

Coal is an important fossil fuel and will also be for the next decades.[1] The only way to achieve the challenges faced by the coal industry is to reduce production costs by improving productivity. Improvement of productivity has become an important goal for today's coal industry in the race to increase price competitiveness. In recent years, underground mining method is becoming popular because of its efficiency and higher productivity. The primary driver behind the research and development effort of longwall coal mining operations is to increase the safety, productivity and efficiency to enhance the mining business.[2] The coal mines work with an aim of obtaining maximum productivity at minimum cost which can be obtained by the incorporation of the longwall mining technique.

Longwall coal mining is a full extraction underground mining method that involves the removal of coal in large blocks or panels using a mechanized shearer.[3] The coal panel is typically 200-450 m wide and can be up to five kilometers in length.[3] 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.[3] Coal cut from the longwall face by the shearer is removed by an Armoured Face Conveyor (AFC) that transports coal to the adjoining gate road for conveyance to the surface.[3] 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.[3] 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 behind the shields.[3] Productivity of the longwall coal mining is complex and depends on variety of factors like reliability, safety and technical parameters of the coal extracting machine. Longwall coal mining is one of the most acclaimed and widely used in underground method for coal extraction. Although the longwall mining technique will provide maximum productivity, this technique is not a suitable option for the condition where the production is intermittent. Because of the harsh working condition, the longwall coal mining machinery will be subjected to sudden shock and vibration which leads to requirement of proper maintenance or replacement of worn out parts in an underground environment which are often difficult and time-consuming. The breakdown of any the longwall machinery will lead to the stoppage of the production of the coal and will cause the revenue loss.

The automation may be the most appropriate solution to overcome the drawbacks of longwall coal mining. The automation is the integration and incorporation of the various field of engineering with computer systems. Production involves repetitive tasks which is tiresome for human worker which leads to defects. The automation in production activity on the other hand can be utilized effectively to perform the repetitive tasks effortlessly which not only reduces defects but also improves the productivity. The incorporation of automation will lead to the monitoring of each and every activity. The monitoring of industrial activity can lead to proper utilization of the machine and also reduces the breakdown of the machine. This paper highlights the various developmental stages of the longwall mining automation. The paper also presents some of the enhanced features of automation such as remote-controlled operation in longwall coal mining. A brief review of major challenges in longwall coal mining automation which has undergone from last 60 years has been presented.

A review of automation in longwall coal mining

In early 1950's, the British underground coal industry had considered developing a automated longwall operation which can be remotely controlled. Ralston et al.,[3] have specified the concept of a Remotely Operated Longwall Face which was referred as 'ROLF' and it was developed for the British government. The experiments were conducted to develop the ROLF and the results were not satisfactory. The results showed that the ROLF did not have the capacity to enhance the production performance. Later in the 1970–80s several researchers explored the distributed system control in mine. None of these research efforts were found to be successful and able to provide a required solution for the problem of automation. King et al.[4] specified the possible utilization of automation in continuous mining operations by using the longwall technique. It was also suggested that the improvement in the health and safety of mine workers will lead to the increase in production. Roger Milne[5] studied the mining technology affecting the longwall coal mining practice and techniques. According to Thomas Carr, the NCB's Deputy Director of mining research and

development (1980), "A telechir is a mobile machine equipped with TV, sensor devices, mechanical arms and hands, and controlled by the skilled human operator situated at the surface." Things (1983) suggested that the future of coal mining required the full combination of automation with telechirs to improve productivity and safety of the worker. The telechir technique was expected to solve the automation problem in longwall mining technique. From the definition of Thomas Carr, it is clear that telechir was considered as one of solution for adding automation to the longwall mining.

Things (1983) have described the telechir would have its own power lighting system directly connected to its TV camera so that it could see exactly whatever it wanted and telechir also utilized the microwave communication system to enable worker on the surface to receive TV pictures for effective monitoring of the operation. The main reason behind the idea of using telechir for longwall mining was to reduce the downtime of the machine and also to provide worker safety. Barham[6] identified many difficulties in the use of telechirs to operate a longwall face remotely based on an 18-month study. Although there was a hope that the telechirs could have been used to overcome the problem of automation in the mining industry, but it failed because of its inaccuracy in positioning, low speed and bad sensing ability. With the invent of computer and its integration with the machines, the next stages of development in automation of longwall mining began. Barham[6] suggested the introduction of automatic and computer controlled machines, which are reprogrammable and designed to manipulate tools for improving the performance of production. The author utilized the standard computer system MINOS which was applied to mine transport, mine environment and machine condition monitoring.

Boutonnat et al.[7] studied the automation and centralized monitoring of longwall type underground equipment's for the purpose of improving safety and working conditions to increase productivity and also to improve efficiency in machine operation through continuous "health monitoring". The author also utilized a Computer Assisted Remote Control program: a direct view remote control system, TELSAFE, which allows one or two machine-operators to control the shearer from a remote place. Basu et al.[8] studied the condition monitoring techniques and presented some studies of condition monitoring in longwall mining machinery. An expert system for condition monitoring purposes was discussed together with several case studies on underground mining machinery maintenance programs. The development of instrumentation for longwall condition monitoring was reviewed with strategies in development of condition monitoring and expert system for longwall mining machinery was proposed.

Holm et al.[1] developed the concept of Shield-Data-Based Horizon Control (SDHC) which integrated data from the roof support as "input and feedback" for longwall coal mining automation. Fink et al.[9] utilized a system with received signal strength (RSS) measurements of common radio modules for longwall mining. An investigation regarding the RSS-based ranging and the localization algorithm was proposed by the authors. Ray tracing was utilized by the author to find an appropriate propagation model and also to define suitable range for different radio frequency bands. Simulation and experimental results were compared for 2.4GHz and sub- GHz radios. Ralston et al.[3] described the critical role of technologies which was required in the delivery of remote and automated capability for longwall mining. The authors concluded with the future challenges and opportunities

to highlight the ongoing scope for longwall automation research and development. Ralston et al.[2] explored the development and implementation of longwall technology to achieve greater levels of automation and increases coal mining performance. Ralston et al.[2] discussed the areas of technical challenge in sensing, decision support, autonomy and human interaction with specific attention given to remote operating centres, proximity detection and systems-level architectures in order to motivate further automation system development. The author also highlighted the significant role of automation components like Remote workstation module in the research and development which are responsible for outcomes like productivity and environmentally safe mining.

Discussion

The above review has shown the various stages of development of longwall coal mining techniques with automation. The automation which once started with ROLF had undergone stage by stage development and lead to the prime features like remote controlled operation, sensor detection, accurate monitoring of the long wall coal mining operation which also leads to worker safety. Automation has succeeded in reducing the human work force. Automation does not necessarily aim at reducing the workers from the mine, but rather removing them from the hazardous mining area. The advancement of computer integrated production and automation to machine will undoubtedly lead to certain machines becoming advanced robots. Automation and remote-control equipment's requires a gradual incorporation into the underground coal mining industry. Many problems may be faced by the mining industry during integration of several machines together. As for instance, the older mechanical equipment has to be fully automated and then the automated machine has to be integrated with the automatic mining sequence.

Automation will strengthen the productivity and economy of a longwall mine. Furthermore, automation brings safer working conditions and reliable operation of the machines. In longwall mining, the integration of automation with the older machine does not focus only on one part of the system, e.g. the shearer. The subsystems also need to be provided with a high degree of automation. Today in an automated system, a monitoring component will be often used to store and provide information to the operator whenever needed. For visualizing the condition of a longwall system can be done by installing monitoring equipments like vision system. This allows the controlling and optimization of the various activities from the surface. Now a day's lot of mines is going towards implementing automated systems to run a longwall face without miners in the mining area. To do this, monitoring equipments can be used which can be operated remotely. The transmission of the data from the machine to the mining database can be sent which could be used to guide the machine remotely. All signals and information are collected in an integrated data base. The study thus shows that the objective such as optimizing the production, maximizing the productivity, reduction in production cost, reduction in energy requirement, reduction in work space, reduction in work force and improvement in worker safety can be achieved by longwall coal mining automation technique.

Conclusion

It is seen that excellent work has been carried out since 1950 on automation which has increased the growth of longwall coal mining. With the development of longwall mining automation, we can obtain the solution to move the workers away from the hazardous mine

areas which will contribute towards improvement in health and safety, reduce machine downtime and increase productivity. It also results in accurate mining methods; reduced production cost, higher productivity, new operation culture, and increased operator safety. The longwall coal mining automation technique has proved to be best means for attaining the objective of maximum productivity and worker safety. Although there were lot of improvement in longwall coal mining automation from 1950's. The development and improvement of any technology has to be upgraded time after time. The next stage of improvement can be obtained by the integration and incorporation of the artificial intelligence and expert system to the existing longwall coal mining automation technology.

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Conflicts of interest

Author declares that there are no conflicts.

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