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Original Research Paper

Improved dust management at a longwall top coal caving (LTCC) face – A CFD modelling approach

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ABSTRACT

Dust management at longwall faces has always been a concern for mine operators. Recent respirable dust monitoring at a longwall top coal caving (LTCC) face indicated that extremely high dust exposure levels have been experienced at the face. Dust contamination from intake ventilation and the incorrect use of ventilation arrangements (i.e. curtains) at maingate (MG) area were identified as the main cause of this issue. Computational Fluid Dynamics (CFD) modelling studies were therefore conducted to investigate the impact of different ventilation arrangements on the dispersion behaviour of respirable dust at the LTCC face, with a special focus on the airflow patterns and the aerodynamics of fugitive dust at the intersection of MG and face. Field investigation was first carried out to observe the dust issue and obtain essential data for the development and validation of base model. Then parametric studies were conducted to evaluate the effectiveness of two different curtain configurations at MG considering the worst scenario of intake dust contamination to face (dust from travel road and beam stage loader (BSL) discharge point flows towards face) with the shearer cutting into the MG. Model results demonstrate that the occurrence of flow separation and incorrect use of curtains account for the main reasons of high dust exposure level at the intersection of MG and face, especially when the shearer is cutting into the MG. Ventilation arrangements at the MG and face entry are critical to minimise the impact of flow separation on the dust flow patterns at the intersection. Based on model results, new ventilation arrangements at the MG and face entry have been proposed and evaluated through which significant dust mitigation effect can be achieved at face entry, contributing to the overall reduction of dust exposure levels along the face.

1. Introduction

Management of dust has always been a challenging issue for underground coal mines. The complicated underground environment and the absence of fundamental understanding on the fugitive dust flow behaviour make the dust mitigation in the underground workings more difficult. The increase in coal production in the past few years leads to a dramatic increase in dust exposure levels in the underground working environment and without adequate protection strategies, Coal Workers' Pneumoconiosis (CWP) or black lung is getting prevalent among miners. For instance, in the US, it is estimated that around 1500 former miners will die from CWP every year [1]. It is also reported that close to nine percent of miners with 25 years or more experience tested positive for black lung in 2005–2006, compared with four percent in the late 1990s [2]. More recently, in Australia, it was reported on the 1st of December 2015 that "four Queensland coal miners have been diagnosed with pneumoconiosis or "black lung" - a potentially fatal disease thought to have been eradicated in Australia more than 60 years ago" [3], and the number has increased to 15 until September 2016 with a former miner died from complications after developing black lung [4]. Further investigations are currently conducted to understand the serious issue and to determine whether there are more miners under the risk of black lung. The situation is estimated to be worse in developing countries where huge amount of coal is produced and occupational hygiene is always neglected due to the fact that safety issues are considered much more important than the occupational health of coal miners.

Longwall mining is currently the dominant coal extraction method in modern underground coal mines. On the basis of normal longwall system, Longwall Top Coal Caving (LTCC) method has

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been developed to extract thick coal seams of 5–12 m at one pass of the shearer (coal cutting machine). The general panel layout and ventilation system at a LTCC face is similar to that of normal longwall mining. The longwall panel width generally varies from 150 to 400 m and the panel length can be up to 3 to 4 km. Roadways are developed on both sides of the panel, then the longwall face is formed by connecting the two roadways at panel ends. Within the longwall face, hydraulic supports or chocks, which can be advanced automatically as the shearer cuts coal from face, are employed to support the roof, thus mine operators are able to work under the protection of chocks' canopy. The longwall coal mining requires effective ventilation to dilute hazardous gas/dust released during mining. Generally, the roadway on one side of the panel, which is usually used to deliver fresh air to the face, is termed as maingate (MG) or headgate, whilst the roadway on the other side, which is used to discharge the contaminated ventilation from face to the main return of the mine, is generally referred as tailgate (TG). A general layout of a LTCC face is shown in Fig. 1, where the ventilation system and coal transport direction can also be observed. The coal cut by the shearer at face will be first transported by an armoured face conveyor (AFC) to the MG end of face (i.e., the intersection of MG and face), then it will be transported to pass through a crusher and a beam stage loader (BSL) before being transferred to the belt conveyor in the MG. Belt conveyor is usually used to move coal out of the panel. It is worth noting that, at a LTCC face, one additional AFC (normally referred as rear AFC) is equipped at the rear of chocks, allowing the transport of caving coal behind face. The coal caving process can also be observed in Fig. 1.

Recent respirable dust monitoring at an Australian LTCC face is shown in Table 1 where it can be observed that extremely high dust exposure levels have been experienced at the face, in particular at positions of chock 70# and 150#. The high dust concentration at chock 8# reveals that there is significant dust contamination occurring at the face entry (face area that closes to MG) which will eventually contribute to the already high dust concentration along face. From the alarming figures it is analysed that dust contamination at the MG area and face entry are severe issues that need to be solved so as to reduce the overall dust concentration along face, which composes the main purpose of this study. Regarding the extremely high dust levels at chock 70# and 150#, dust from upstream ventilation, unpredictable coal spalling (the phenomenon of coal falling from face due to the high stress from roof, and it is more commonly seen ahead of the leading drum as shearer cuts coal from face) along face and coal caving behind chocks are thought to be the major dust sources, which is beyond the focus of this study and will be investigated in future studies.

Table 1
Respirable dust monitoring result at an Australian LTCC face.

Position	Respirable dust concentration (mg/m^3)
BSL discharge	1.30
8# chock	4.4
15# chock	2.41
70# chock	11.61
150# chock	9.28

In order to reduce the dust level in the intake ventilation to the LTCC face, a curtain positioned on top of the BSL and another curtain hanging under the MG chocks behind the rear AFC had been used in the MG area and face entry; however, dust monitoring results as indicated in Table 1 demonstrated that the employed curtains were not effective to control the dispersion of fugitive dust at the MG area and face entry. Field observations and discussions with mine operators also confirmed the severe dust contamination to face by intake ventilation. Therefore, there is an urgent need to scientifically understand the ventilation and dust flow patterns at the intersection of MG and face so as to optimise the positions of curtains for improved dust control, in particular at the LTCC face where the coal transport system is more complicated than normal longwall face due to the use of a rear AFC for caving coal transport behind longwall chocks.

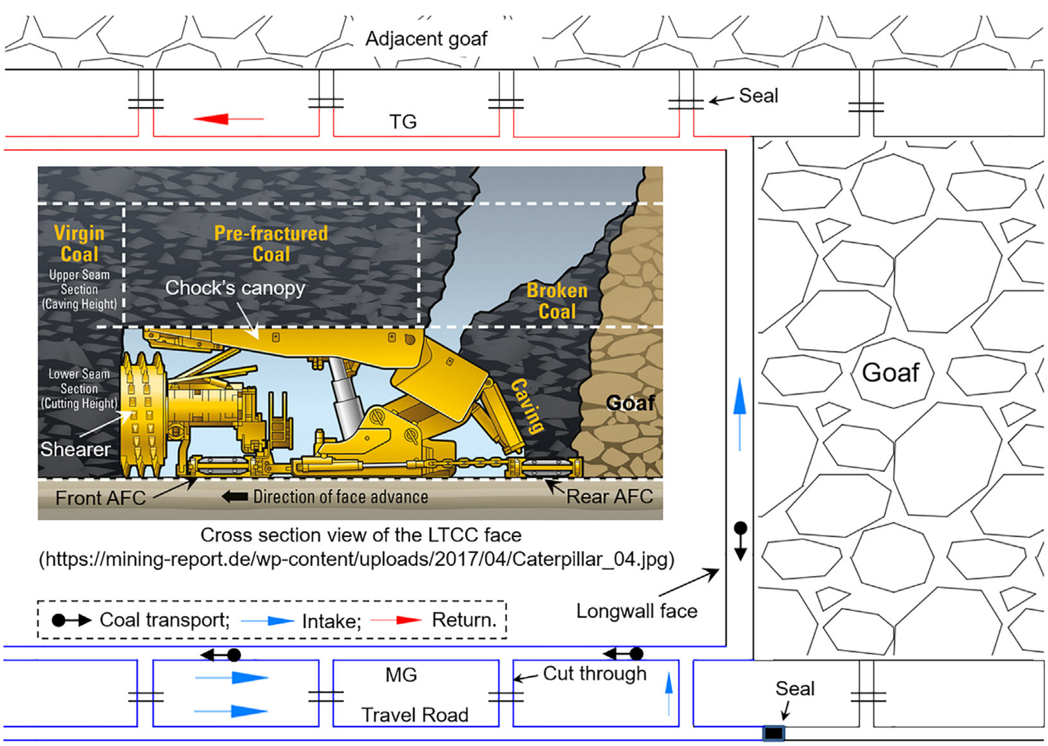

Fig. 1. General layout of a LTCC face [modified from [5]].

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