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Proactive goaf inertisation for controlling longwall goaf heatings

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Abstract

Deep oxygen ingress into the goaf can lead to spontaneous heatings particularly during face stoppage or slow face retreat in the panel. This requires the deployment of proactive goaf inertisation strategies based upon detailed understanding of goaf gas flow patterns and distribution characteristics. An integrated approach combining goaf gas monitoring, Computational Fluid Dynamics (CFD) and field trials has been used for the development of effective goaf inertisation strategies in underground coal mines. CFD simulations indicate that inert gas injection close to the face is ineffective even at higher flow rates in the order of 1.0 to 2.0m^3/s. Inert gas needs to be injected at 200m to 400m behind the face at the rate of about 0.5m^3/s to achieve effective goaf inertisation in most cases. Proactive inertisation strategies developed during the course of the study were highly successful in reducing oxygen ingress into the goaf and in achieving effective goaf inertisation by reducing oxygen levels below 5% at 200m behind the face. The study also indicates that just injecting inert gas into the goaf does not ensure prevention of heating incidents in the entire length of panels or all longwall panels. A number of parameters such as panel ventilation system, goaf caving conditions, and longwall retreat rate and goaf gas drainage can make a specific inertisation strategy ineffective and the inertisation strategies need to be modified based on the specific conditions at the mine sites.

Keywords: CFD; goaf inertisation; spontaneous heating; longwall mining

1. Introduction

The number of heating incidents in longwall panels has increased significantly in recent years, leading to major production losses and safety risk for a number of mines in Australia. Most of the new underground coal mines in the Hunter Valley and Bowen Basin have a moderate to high susceptibility to spontaneous combustion (sponcom). The coal seams in these new areas are generally thick and the risk of sponcom/heatings increases significantly during longwall mining due to the large quantities of broken coal left behind the chocks and its exposure to high oxygen levels in the goaf. This poses a major risk to the safety of the people and economic viability of the modern highly capital intensive coal mines.

In Australia, research work in inertisation area has led to the development and demonstration of inert gas generators. This solved one of the major problems of supplying inert gas to the mines located in remote parts of Australia. However, a critical review of the major heating control operations shows that the success or failure of the

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inertisation operations depends entirely on the design of inertisation strategies. A detailed understanding of the flow patterns and distribution of gas flow in the goaf is necessary not only to improve the control of goaf gas emissions but also for spontaneous heating prevention strategies such as the injection of inert gas.

CFD modelling has been used for the development and demonstration of pro-active inertisation strategies with the objective to reduce the risk of spontaneous heatings in active longwall faces, in particular under unexpected scenarios such as during slow retreat/face stoppage due to difficult geological conditions [1,2,3,4]. The proactive inertisation strategies developed during the course of this study have played a crucial part in containing the onset of spontaneous combustion in two longwall goafs in Australia [5].

This paper presents the results of CFD modelling investigations and field studies in an Australian longwall panel.

2. Oxygen ingress patterns and spontaneous heatings in longwall goafs

To investigate the effect of proactive inertisation in longwall panels, it is very important to characterise the initial oxygen ingress patterns in longwall goafs under different mining conditions. This involves a detailed monitoring of the gas distribution behind the face under different ventilation and operational conditions at Longwall Mines in Australia.

As shown in Figure 1. The longwall panel has access around the perimeter of the panel which enabled extensive monitoring of gas distribution in the goaf on both maingate (MG) and tailgate (TG) sides. A snapshot of the typical goaf gas distribution behind the longwall face is presented in Figure 1. Results show that intake air ingress on the maingate side of the panel was very high, with the oxygen level at more than 17% even at 400m behind the longwall face. Oxygen ingress on the tailgate appears to extend only up to 100 m behind the face due to higher goaf gas emissions in the panel. This level of high oxygen ingress could lead to heating development in the goaf, particularly during face stoppage or slow face retreat in the panel.

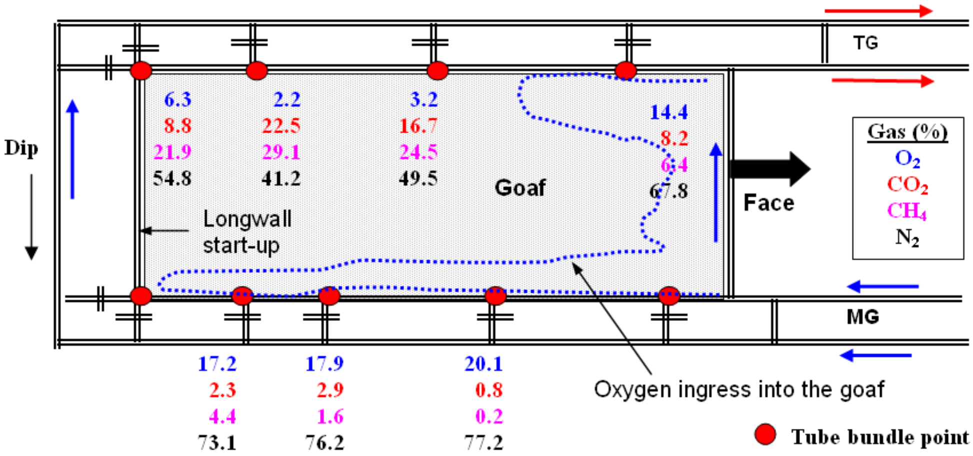

Fig.1. Typical gas distribution in a longwall goaf

3. CFD Simulations

3.1. Base model simulations

A number of base case models have been developed to represent various longwall panel geometries under different mining and gas emission conditions based on the preliminary field investigations carried out at a number of mine sites. The base models for the longwall inertisation studies were typically 1km in length along the panel, 250m in width and 80m in height to cover the immediate high porosity caving regions in the goaf. Goaf gas emission was varied between 100l/s and 3,000l/s to represent different goaf gas environments.

The results of the typical base case simulations for a longwall panel with face air quantity around 50m^3/s are presented in Figure 2, showing the oxygen gas distribution in the goaf. Results show that oxygen ingress into the goaf was high with oxygen levels on the maingate side well over 14% at 350m behind the face and over 10% even at 600m behind the longwall face.

Analysis of the results showed that intake airflow and ventilation pressures seem to have a major influence on gas distribution up to 50m to 150m behind the face, and beyond that, goaf gases buoyancy seems to play a major role on goaf gas distribution. Base case simulation results presented in Figure 2 tallied well with the results of field goaf gas monitoring studies.

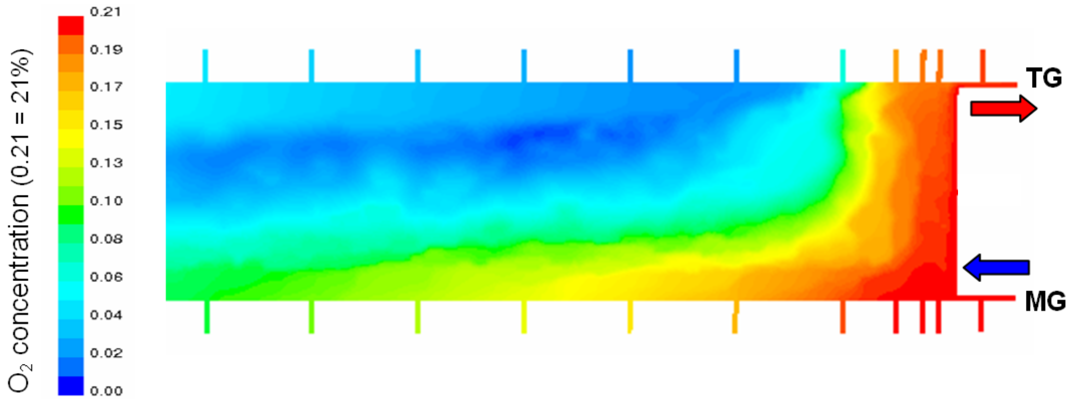

Fig. 2. Oxygen distribution in the longwall goaf – a base model result

3.2. Parametric studies

The validated base case models were then used for extensive parametric studies involving changes in inert gas injection locations, inert gas flow rates and different inertisation strategies to investigate their effect on goaf inertisation in active longwall panels.

3.2.1. Effect of inert gas flow near the face

Modelling results indicate that inert gas injection at 30m behind the face at a flow rate of 0.5m^3/s has negligible effect on oxygen ingress patterns into the goaf, with oxygen levels well over 13% at 300m behind the face. Inert gas injection even at 1.0m^3/s has only a minor effect on goaf gas distribution, with oxygen concentration around 10% at 300m behind the face. Further simulations indicate that when inert gas is injected within 10 to 30m behind the face, inert gas flow rates well over 5m^3/s are required to substantially reduce oxygen ingress into the longwall goaf. These results indicate that inert gas injection just behind the face is not an effective strategy.

3.2.2. Effect of inert gas injection at locations behind the face

The effect of inert gas injection at a number of different locations behind the longwall face was investigated in this set of simulations. A comparison of the results of investigations with inert gas injection at 60m and 220m behind the face on maingate side is shown in Fig.3. In both the cases, inert gas was injected at the low flow rate of 0.5m^3/s. Oxygen distribution in the goaf for base model simulations is also shown in the Fig.3a for comparison purposes. Fig.3c shows that inert gas injection at 220m behind the face resulted in substantial reduction in oxygen ingress into the goaf, with oxygen levels reducing below 5% within 100m behind the longwall face. Results of the simulations indicate that inert gas injection deep in the goaf results in effective goaf inertisation, even at low inert gas flow rates of 0.5m^3/s.

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Further simulations with other inert gas injection location scenarios indicated that inert gas injection even at other deeper locations in the goaf, between 200 to 400m behind the face, could result in effective goaf inertisation for the modelled longwall panel conditions. Although the exact optimum location for inert gas injection for any longwall panel depends on site specific parameters, these modelling simulations indicated that inert gas injection at around 200 to 400 m behind the face would be far more effective than inert gas injection close to the face.

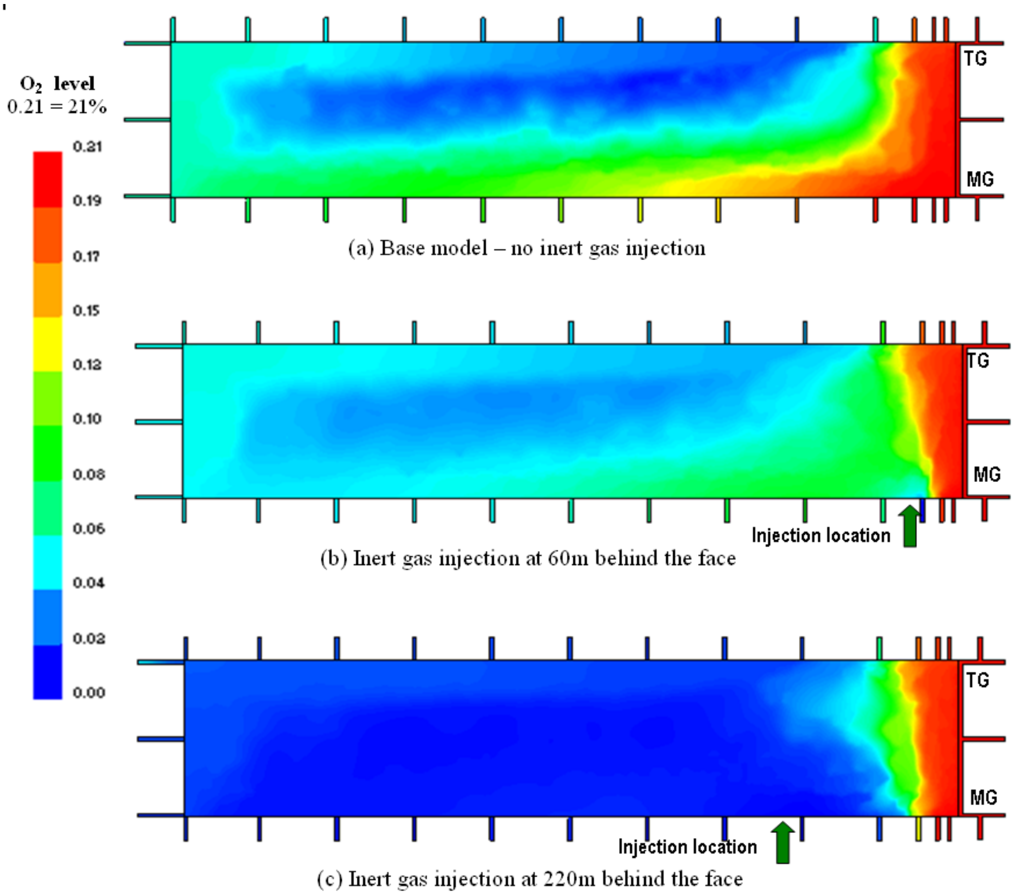


Fig. 3. Effect of inert gas injection at different locations on goaf inertisation

3.2.3. Remote inertisation via surface goaf holes

In case of access problems in underground workings, such as after withdrawal of personnel from underground workings, the only possible means of goaf inertisation may be via surface drilled boreholes or those existing surface goaf holes for goaf gas drainage. CFD simulations were conducted to investigate if goaf inertisation can be achieved by injecting inert gas through surface goaf holes or in combination with inert gas injection in underground workings. Fig.4. shows the simulation results of goaf inertisation via goaf hole injection of boiler gas at various locations and flow rates. The modelling results indicate that an improved goaf inertisation effect could be achieved by injecting inert gas via surface boreholes. In this case, the modelling results show that by injecting inert gas on both side of the goaf via surface goaf holes would produce a better inertisation result than simply injecting inert gas on one side of the goaf. Similarly it is also important to understand goaf gas distribution patterns so that the correct injection locations can be identified to achieve the maximum goaf inertisation effectiveness.

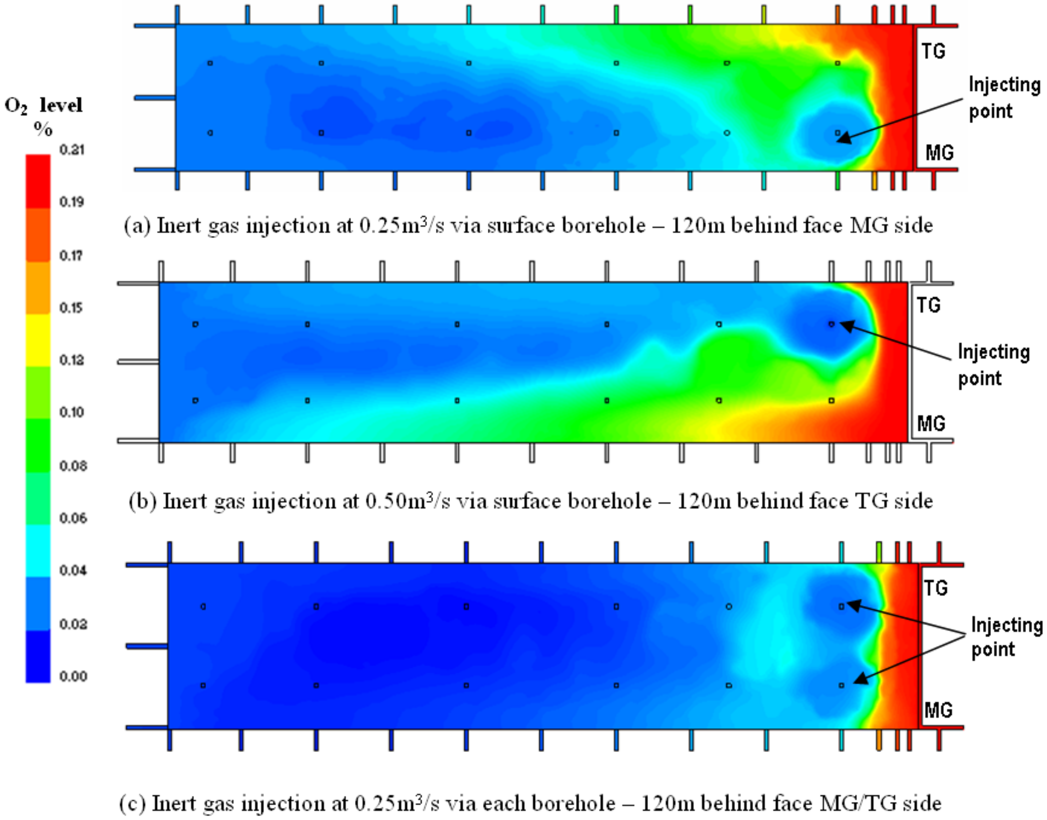


Fig. 4. Effect of inert gas injection via surface goaf holes on goaf inertisation

4. Field applications

The longwall panel 105 at Mine A has advanced for some 550m from the panel start-up line. Due to roadway roof control problems, the tailgate (TG) was collapsed and as a result the longwall has to be halted for the installation of a new tailgate. As the face stopped, there were signs of spontaneous heating (high CO and H_2) developing in the goaf, and consequently pro-active goaf inertisation was considered to reduce oxygen ingress into the goaf to prevent the heating development. Fig.5 shows the goaf gas distribution in behind the longwall panel after the collapsed tailgate was closed and the face was ventilated with auxiliary fans at $10m^3/s$. The airflow penetration into the goaf was high on the maingate side with oxygen level over 10% at some 300m behind the longwall face.

While the face was in stoppage, proactive inertisation was carried out through the existing concrete drop holes and additional goaf holes specifically drilled for this goaf inertisation. The proactive inertisation strategy for this panel consisted of injecting inert gas into the goaf through the surface boreholes located on the maingate and tailgate sides of the panel at a combined flow rate of $0.6m^3/s$. A combination of inertisation strategies involving inert gas injection either via a single hole or a combination of holes on both sides of the goaf simultaneously were adopted for inertisation at this mine site. These combinations have been identified in the CFD modelling studies as the most optimum options for this case.

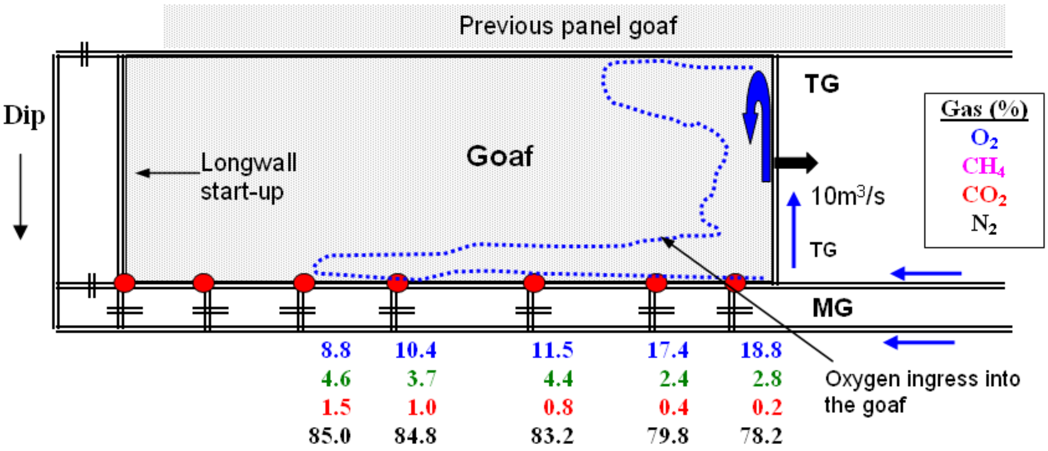
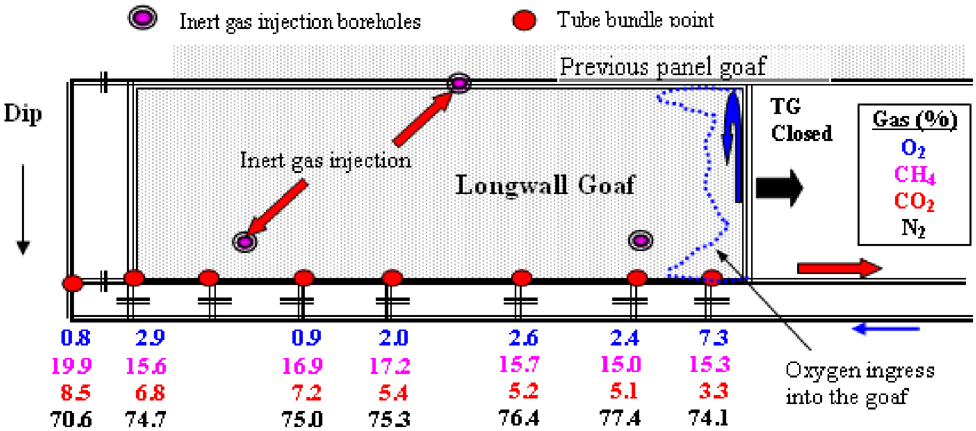
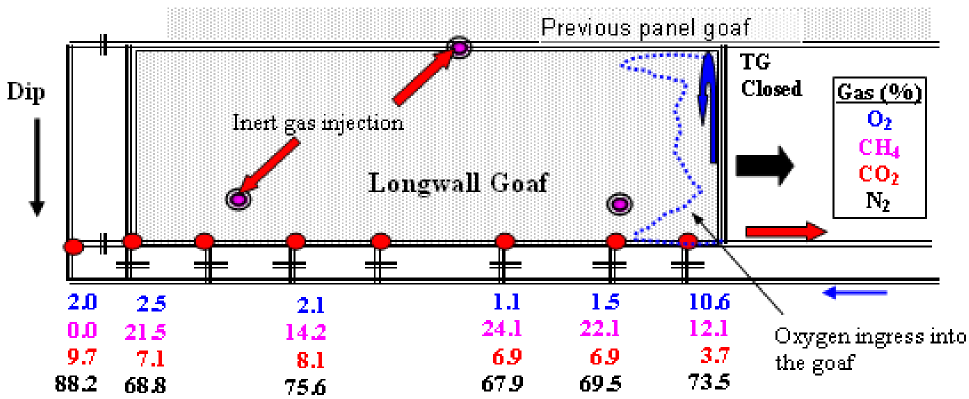


Fig. 5. Goaf gas distribution behind the longwall – after tailgate closure



(a) Goaf gas distribution behind the longwall – **1 day** after start of inertisation



(b) Goaf gas distribution behind the longwall – 2 weeks after start of inertisation

Fig. 6.Goaf gas distribution behind the longwall after inertisation

Fig.6. shows the results of goaf gas distribution in the longwall goaf after injection of boiler gas via the boreholes on the tailgate and maingate sides of the panel. The goaf gas monitoring data indicate that the goaf inertisation operation has worked well in narrowing down the size of the high oxygen ingress zones in the longwall goaf. Field results show that the oxygen level was below 3% at the second cut-through behind the face, i.e. 100m behind the face. This very high reduction in oxygen ingress was due to a combination of inert gas injection and reduction in intake airflow. The results indicate that this proactive inertisation strategy was highly successful and had substantially reduced oxygen ingress into the longwall goaf, and as such has helped the containment of spontaneous combustion during the stoppage of the longwall face while a new tailgate was being re-installed.

Field study results at other mine sites also demonstrated that the proactive inertisation strategies were highly successful in converting the general goaf environment into an inert atmosphere. These field studies showed that it is possible to reduce the oxygen ingress distance in the goaf to within 200 to 300m behind the face by implementing appropriate proactive inertisation strategies.

5. Conclusions

CFD modelling techniques have been used to investigate the effect of various inertisation strategies on goaf oxygen ingress patterns. The results of the base-case CFD models tallied well with the results of field monitoring studies. Inertisation simulations indicated that inert gas injection close to the face would be ineffective even at higher flow rates in the order of 1.0 to 2.0m^3/s. Modelling results indicated that inert gas needs to be injected at 200m to 400m behind the face at the rate of about 0.5m^3/s to achieve effective goaf inertisation in most cases.

Appropriate inertisation strategies need to be developed for any specific field site based on the site conditions. Field studies carried out at mine sites demonstrated that the proactive inertisation strategies developed were highly successful in reducing oxygen ingress into the goaf and in achieving effective goaf inertisation. Field results showed that oxygen levels were below 5% to 6% at 200m behind the face after implementation of the proactive inertisation.

It must be noted that just injecting inert gas into the goaf does not ensure prevention of heating incidents in the entire length of panels or all longwall panels. A number of parameters such as major changes in panel ventilation system, goaf caving conditions, longwall retreat rate and goaf gas drainage can make a specific inertisation strategy ineffective and the inertisation strategies need to be modified based on the changed conditions at the field sites.

Acknowledgements

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