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The management of mine ventilation and many health and safety problems in the coal mining industry require sound knowledge and analysis of the mechanism of fluid flow, airflow, mine gas or particle interactions.

Computational Fluid Dynamics or CFD has become a powerful tool to assist mining engineers and find solutions to these problems. CFD is a branch of fluid mechanics that embraces mathematics and numerical solution, by computational methods, of the governing equations which describe the motion of fluid flow, the Navier-Stokes equations, continuity and any additional conservation equations, such as energy or species concentrations.

Nowadays high performance computers are used together with sophisticated CFD code such as ANSYS Fluent or CFX to perform the calculations required to model the interaction of liquids and gases. For mining related ventilation, health and safety problems, this would typically require visits to the mine site to discuss the problem with the ventilation engineers and examine relevant data to clarify any technical issues before developing the CFD models. The base CFD model has to be validated against field survey data before it can be used for parametric studies.
The management of mine ventilation is critical to the maintenance of a comfortable atmosphere for workers working in underground coal mines. The ventilation supplied to the underground longwall face must be sufficient to dilute hazardous gases such as methane and dust contaminations in addition to providing fresh air to longwall operators.

CFD modelling has been used to understand airflow and dust flow patterns, and the development of various control strategies for gas and dust mitigation on longwall faces. CFD has also been used to study the dispersion of smoke, shock wave, heat and hazardous combustible gases in mine ventilation networks.

Rapid roadway development is a necessity for satisfying the production schedule of high performance longwall extraction. This involves heavy duty machinery such as continuous miner (CM), bolter and shuttle cars operating in a confined space to which sufficient ventilation must be provided to dilute strata gas and dust. CFD modelling can be used to simulate airflow behaviour of different ventilation strategies and the installation of various sprays and water mist air movers for dust diversion and suppression.

Methane gas emissions from caved longwall goafs can potentially lead to longwall production halts due to gassing out (excessive gas emissions over the safety limit), and in the worst case, catastrophic mine explosion accidents. Methane will liberate from adjacent seams or residual coals and migrate towards the goaf area as a result of enhanced permeability and ventilation pressure differences.

CFD modelling has been used to study goaf gas flow behaviour in response to different ventilation systems and the design of optimum goaf gas drainage to reduce fugitive gas emissions into mine ventilation systems. CFD models can be used to predict goaf gas flow distribution characteristics and identify ‘methane rich zones’ to which gas drainage boreholes can be tapped to maximise the capture of high purity gas.
Ventilation in underground coal mines can lead to the occurrence of spontaneous combustion or heating in longwall goafs by providing sufficient oxygen to support the slow oxidation of residual coals left in the goaf or chain pillars. CFD simulations are used to predict the ingress of oxygen into the goaf and identify those zones that are most susceptible to spontaneous heating, and the development of proactive goaf inertisation strategies to prevent the onset of such incidents.

CFD modelling results are used to select the most suitable ventilation systems with less air leakage into the goaf, and the optimum position and inert gas injection rate should goaf inertisation be needed to suppress the development of a goaf heating.

CFD models are also used to investigate the dispersion of gaseous products including carbon monoxide (CO) and hydrogen (H2) evolved from goaf heating therefore help the early detection and accurate location of these heating spots before they develop into a dangerous goaf fire.

In brief, CFD modelling can be used as a powerful tool for solving many ventilation problems in underground coal mines. These include ventilation in longwall face, mine fires, goaf gas emission, dust mitigation, gas explosion, gas drainage and fire inertisation.

The usefulness of CFD has been demonstrated in the development of new ventilation strategies and technologies for handling these issues with significant benefits to mine operators.

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CFD modelling of ventilation ingress into longwall goafs and zones liable to spontaneous heatings.