Real-Time Airflow Monitoring and Control Within the Mine Production System

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ABSTRACT

Computer software has been developed to link real-time information generated by underground mine ventilation airflow monitoring sensors into a network simulation program to undertake network simulations and allow interpretation of key system data and operational changes. Results were used in the development of a computerised monitoring and simulation system to provide immediate or real-time data on air behaviour within each branch of an underground mine ventilation network through linking of sensors to the ventilation network simulation software. The outcome of the project is an online system that can report changes in the mine ventilation system, allow causes of changes to be isolated and rectified, improve balancing of available air throughout the mine, allow improved approaches to regulator setting and dispense with much of the labour used for underground ventilation measurement. The work activities in both coal and metalliferous Australian mines have involved examination and modelling of regulators, software modification and considerable mine site testing and optimising activities.

There is some discussion on approaches to control of flow through ventilation systems with increased information. New systems will be part of a total mine information management system. They will have to be cost effective and justified by gains in productivity. New systems will need to provide simulation of contaminant production such as diesels, vehicle heat, strata heat, radiation, blast fumes and other gases. More robust real-time ventilation simulation systems will be required. Personnel and vehicle identification and production tracking will be collected to provide integrated ventilation system monitoring and control.

This paper examines a study to gain greater understanding of computerised real-time airflow monitoring and control within the mine production system to provide immediate simulated information in each branch of an underground ventilation network and to allow interpretation of key system data and operational changes. A case study implementing a real-time airflow monitoring and control is discussed. Approaches to control of flow through ventilation systems with increased information are discussed. The concept of a system that can be linked to or be part of a total mine information management system is developed. Such a system can form the base for mine automation that allows mines to incrementally and cost effectively implement monitoring and control to further seek gains in productivity.

INTRODUCTION

The application of computer technology within the mining industry for design and system optimisation has developed significantly over recent decades. Solutions now exist for many of the problems associated with overall mine design and development and operational monitoring/control. The adoption of this technology has allowed an increased emphasis on the design, safety and economic conditions within which the overall mining system operates.

As an important consideration in underground coal mining operations, ventilation network design and remote monitoring has also been increasingly computerised. The fundamental requirement of ventilation is to provide controlled air distribution within the underground mining operations to satisfy statutory and safety requirements with respect to air quantity and quality. Ventilation design facilitates this distribution using modelling and predictive tools. The analysis of an operational ventilation network during both normal and abnormal conditions can be very complicated both on a theoretical and analytical level and in practice requires computer based solutions. Remote monitoring systems provide the ability to observe many aspects of the underground environment. The application of monitoring to the ventilation network improves understanding of airflow, pressure, psychrometric and gas concentration observations.

The study examines the integration of real-time environmental monitoring and ventilation network analysis to develop systems that allow refinement of ventilation design and predictive modelling and provide an analysis of the operational ventilation network to identify abnormal conditions. The development of 'what if' scenarios can then be simulated using a refined and robust ventilation model with a high degree of confidence in the predicted behaviours.

Real-time control over a ventilation network can be achieved through the utilisation of modern monitoring systems and controllable ventilation components. Through integration with a calibrated model representative of the actual ventilation conditions and identified airflow requirements, control and optimisation of the ventilation network may then be achieved with significant safety and economic benefits.

One of the objectives of this study has been to develop a computerised monitoring and control system to provide immediate or real-time information on each branch within an underground ventilation network. The system measures airflow or air pressure changes in selected ventilation branches and simulates flows through all other branches. This approach to ventilation network understanding provides improved understanding of airflows through all mine sections and allows quantification of peak, instantaneous and average readings and possibly heat, gas or other contaminant levels for production purposes.

It allows mine airflow balancing through parallel splits to be undertaken. It serves as a useful aid to incident and emergency management. The popular Australian ventilation modelling program VENTSIM has been used as a simulation engine within the system. This software has been altered to accept real-time information generated by underground mine ventilation monitoring sensors, undertake network simulations and interpret key system data and operational changes.

The system can be operated as an independent entity, with no effect on the existing mine information and monitoring system or could be part of a total mine information management system. Once the simulation program has updated readings it can remodel the whole mine ventilation system, report the flows in all branches and compare individual branch readings with expected values. If flows vary significantly, an alert signal can be initiated to question why the change has occurred.

This paper examines a study to gain greater understanding of computerised real-time airflow monitoring and control within the mine production system to provide immediate simulated information in each branch of an underground ventilation network and to allow interpretation of key system data and operational changes. A case study is discussed. Results of a four mine comprehensive survey on attitudes to implementation of real-time airflow monitoring and control are given and analysed.

REAL-TIME MINE VENTILATION MONITORING

The ventilation in a typical Australian mine serves a number of functions and most importantly provides fresh air and oxygen for miners underground by controlling the level of strata gases, other

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noxious gases, dust and particulates from sources such as diesel vehicles and temperature in work places. It may also assist in controlling the temperature of exposed broken coal or ore to manage heating from spontaneous combustion.

The quantity of air flowing through the mine is also related to atmospheric pressure, which affects the differential between the fan pressures and pressure at mine intakes. It is also necessary to balance airflows in different parts of the mine through use of a mixture of flow controls (doors and regulators) and supplementary auxiliary or booster fans.

Computer ventilation flow simulation models are used to analyse and design mine ventilation systems. These are static models that make use of the existing data and proposed layouts to predict, design and optimise the ventilation systems for underground mines. These ventilation models can also be used to select optimum fan combinations for underground mines. There is a need to develop dynamic and real-time ventilation models to deal with emergencies or unforeseen situations. Computational Fluid Dynamic (CFD) programs are available for airflow dynamics modelling, but they are computer intensive and restricted for use in analysis of flow in limited areas such as working face areas.

There is usually not enough information gathered in the mine to measure ventilation performance in real time and to implement any necessary changes. It has been appreciated for some time that if real-time modelling of ventilation is to be developed, better sensing of gas concentrations, air pressure and air velocity throughout the mine and improved mine ventilation models are needed.

The mine atmosphere must comply with Australian state statutory regulations. The required dilution rates with fresh air can be calculated in a relatively straightforward manner where there is a constant supply of pollutants. This is not always the case and it may be difficult to predict pollutant loads where their production is erratic, for example with diesel equipment which does not operate continuously.

Sampling of both the quantity and quality of the underground air is carried out routinely in Australian mines, for example tube bundles are used in coal (and have been used in some metalliferous mines) to collect samples continuously for analysis at a central analysis point located on the surface. Depending on the length of the sample tubes, there may be more than a half hour delay in receiving an analysis reading. Instantaneous readings can be obtained from electronic gas sensors distributed through the mine. Most coal mines use tube bundles and analytical systems attached to a computer system that has set warning levels to alert the mine at the onset of high risk conditions. These are usually stand alone systems connected to a mine-wide monitoring and database management system. Gas data analysis and interpretation software, such as developed by Simtars, have also been installed at a number of Australian coal mines to obtain online analysis of the gas distribution and trends in gas concentration changes at various places in the mines.

The first indications of heating or fires in mines are normally seen in gas concentration changes measured in the ventilation air. Gaseous products of heatings and fires are related to the temperature of the coal and an initial heating will be indicated by an increase in carbon monoxide. At higher temperatures hydrogen and higher hydrocarbons are generated, and the percentages of different gases give a reliable indication of the temperature at the seat of a fire.

An analysis of the spatial distribution of gases within the mine assists in indicating where the heating and source of gases is in the mine. It cannot be assumed that normal ventilation flow continues once a heating or fire commences, as buoyancy effects can reverse flow directions. Modelling is required to supplement results from monitoring to determine what is happening in the mine. The Simtars SAFEGAS system includes interpretation of the significance of gas analyses and plots the standard ratios of gases that are used to determine temperature of fires and the potential for mine explosions related to the gases produced by coal oxidation and fires.

Within the underground mining environment fires represent a serious potential threat to both human life and the operation generally. The outbreak of a mine fire can be seen to cause disturbances to the normal operation of a ventilation network. This is due to the thermal and chemical products of a mine fire creating unsteady, transient states in the airflows and the close relationship between the ventilation process and mine fire can be observed through the use of mine fire simulation programs such as VENTGRAPH (Dziurzynski, Tracz and Trutwin, 1988). The interdependence between fire affecting mine airflow and the available mine airflow altering characteristics of a fire through availability or lack of oxygen has been illustrated by Gillies, Wala and Wu (2004).

Development of real-time airflow monitoring and control systems

Real-time ventilation monitoring and automated control is a relatively new and innovative method of depicting an underground mine environment from alternative locations on a continuous basis. The concept of computer application has been prevalent in the mining industry since the 1960s. However, advancements in the field of continuous monitoring and remote control have only surfaced in the last decade and application to larger, more complex underground networks is still forthcoming.

With the two primary functions of mine ventilation being the adherence to statutory health and safety requirements and the distribution of air to support life and control various environmental aspects, the provision of such a capability is becoming more complicated with the development of larger-scale mining operations. Maximising operational efficiency has led to the development of real-time ventilation monitoring and automated control systems to reduce ventilation downtime and hence production losses. Due to the unique nature of underground conditions, different capabilities are required for different operational sites. As such, it is envisaged that the application of continuous monitoring and control to a simulated ventilation network will account for the detection of environmental aspects such as gas concentrations, heat load and radiation, in addition to airflow quantity and differential pressure.

The benefits that can arise from real-time ventilation monitoring and remote control capabilities may be observed from a technical, economic and safety perspective. By understanding the prevailing conditions of an underground network, personnel may plan ahead and optimise relevant development and production activities on the basis of long-, medium- and short-term planning principles. From an economic perspective, less downtime will be encountered, since controls may be adjusted immediately upon identification of a ventilation problem. Consequently, the capacity of the operation to undertake unobstructed production will be enhanced. Finally, adequate air will always be supplied to personnel and evacuation can be undertaken immediately upon earlier detection of the problem.

Although real-time ventilation monitoring and remote control capabilities have been developed for small- and medium-sized applications, such a system has yet to be proven in a large-scale operational environment. A number of factors weigh heavily against the successful installation of such a system, however, with the application of appropriate strategies and procedures, significant network improvements may be generated with minimal impact on the required infrastructure and services.

As preliminary work, two small initialisation projects were completed. These provided an opportunity to obtain a broad understanding of ventilation monitoring systems that are currently utilised in underground operations and the range of modern technologies presently available through undertaking of an industry survey. As part of the work an industry survey gave strong evidence indicating growing interest in the utilisation of real-time ventilation and simulation systems.

To obtain practical experience successful trial exercises connecting mine airflow monitors to the Australian ventilation network program VENTSIM were undertaken using the University of Queensland Experimental Mine (Mayes, 1998) and an operating coal mine at Bowen Basin in Queensland (Gillies *et al*, 2000).

Under these projects additional executable programs and a macro were created performing as the interface data transformation and conversion intermediates to enable VENTSIM to gain access to the real-time ventilation information produced by the real-time ventilation monitoring system. The macro and executable programs were created solely for fulfilling the requirements of the VENTSIM data import specification. The project has substituted these systems with simpler, more efficient data transformation methodologies (Gillies *et al*, 2000).

These trial exercises were successful. It could be seen that ventilation changes in any selected airway with sensors caused the VENTSIM model to resimulate the whole mine network and output the changed flows in all airways Through utilisation of the system an economical, fast and effective way has been achieved to monitor and predict the ventilation environment in a selected area, or in the entire underground workings.

Subsequently, Queensland coal and base metal mines at three sites have been supporting research to allow the latest electronic instrumentation and simulation software to be used to improve mine ventilation. The aim of this funded foundation mine ventilation research was to develop a computerised monitoring and simulation system to provide immediate or real-time information on each branch within an underground ventilation network through linking of sensors in a small number of selected branches to the ventilation network simulation software. Software has been developed to link monitoring sensor real-time information generated by underground mine ventilation instruments into the simulation software to undertake network simulations and allow interpretation of key system data and operational changes.

The project commenced in late 2000. The first stages have involved selection and purchase of appropriate instruments and communication links, system calibration and design of software links. A major section has involved investigation and mathematical modelling of impedance characteristics of a number of types of underground regulators. In many cases sensors measuring differential pressure drop across regulators and accounting for leakage are used to give accurate airflow readings.

The ventilation simulation program used is VENTSIM, which has been modified as part of the project to allow input of real-time digital data. VENTSIM is now available with 'real-time' routines built in to allow reporting of airflow or gas readings and illustration of mine network schematics. These routines have been developed by the Australian VENTSIM author, Mr Craig Stewart in conjunction with this project. They are available in a new form of VENTSIM accessible to all VENTSIM owners.

The outcome of the project is an online system that can report changes in the mine ventilation system, allow causes of changes to be isolated and rectified, improve balancing of available air throughout the mine, dispense with much of the labour used for underground ventilation measurement and checking, improve power usage and assist emergency incident management. The main work activities involved software modification and considerable mine site installation, testing and optimising activities (Gillies *et al*, 2004).

One of the Queensland operators has, in parallel with the project, developed an automated system for control of airflow. This involved the use of a robust 'roller-door' form of regulator that can be remotely operated from the surface (Figure 1). Differential pressure is measured across each regulator and through understanding of regulator impedance, a quantity flow's value is derived. Mine control operators are able to set regulators to deliver recommended Mine Level flows. Prior to blasting all regulators can be to be opened and then reset at the beginning of the subsequent shift. The system also reports gas concentration levels in mine air passing through each regulator. Gases sensed are carbon monoxide, nitrogen oxide, nitrogen dioxide and sulfur dioxide.

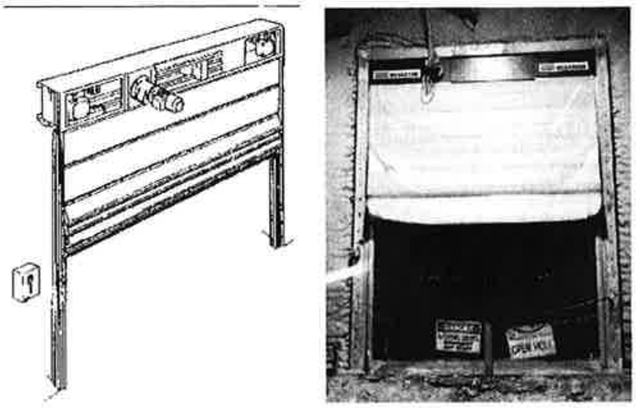

FIG 1 - Schematic and photographic views of a roller door regulator.

One major point of interest in such a system is the setting of the position of each remote controlled regulator at the beginning of each working shift. As the mine is not over-ventilated, it is important to maximise the availability of ventilation air to the active levels to effectively dilute the contaminants. The setting of remote regulator positions is an iterative process as once one regulator is positioned such that the required quantities of airflow are delivered to working areas on a particular level; the airflows on other levels are disturbed.

It is important that the process is efficient with respect to the time it takes (it should be quick enough to perform before the underground mining work is underway each shift) and the ease in which it can be done; that is it should be able to be learnt easily so that all personnel involved in the process can conduct it accurately from the early stages the process is put into place.

Ball (2003) suggested that procedures for the ventilation and shift engineers to follow on a shift-to-shift basis should include:

- periodic updating of the VENTSIM model;
- calculations of shift-to-shift airflow requirements;
- real-time linking to VENTSIM; and
- end of shift blast time remote regulator positioning to minimise re-entry times and risk of blast damage to the regulators.

To avoid regulators being damaged by air pressure resulting from nearby blasting, it is possible to incorporate a pressure venting rupturing device or arrangement using low rigidity or lightweight materials in the structure of the regulators as demonstrated in Figure 2. The construction is so designed that when a blasting pressure wave arrives at the regulator it will be released through the venting arrangement without causing physical damages to the regulator structure.