Fighting the dangers of subterranean methane outbursts

Virtual Mine

Prof. Wacław Dziurzyński develops techniques for monitoring gas flows in mines

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Underground methane can be highly lethal, appearing suddenly and mixing with air to form a strongly explosive gas. Dealing with methane quickly and safely requires an efficient system of ventilation and monitoring, ready for any scenario

Underground coal mining has always been a dangerous endeavor. Despite constant efforts to perfect mining methods, quality control systems, and mining safety, unexpected situations still do sometimes occur, mainly due to human violation of the age-old subterranean balance. Large empty hollows practically do not occur naturally in bedrock (aside from karst or volcanic regions), so when mankind creates an excavation all the liquids and gasses contained in the surrounding rocks begin to leak into it. That causes problems especially in coal mines, which usually have large quantities of methane. Artificial airflows are maintained in such mines to ensure the proper atmosphere for miner safety, in line with mining industry regulations. Ventilation systems have to bring the optimal quantity of air to all the mining excavation areas in use, sometimes with a total length of several hundred kilometers.

In coal mines, due to the constant methane hazard, proper ventilation also has to be ensured for abandoned excavation areas, i.e. the hollows left behind by previously mined coal deposits, whose volume can run into the millions of cubic meters. Although that is already an extraordinarily complex task, such ventilation systems also have to be capable of reacting to emergency situations and catastrophes. Despite the constant modernization of coal mining techniques, such situations do continue to occur - to name just the recent methane outburst at the Zofiówka mine or the more

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Gas flow measurement apparatus installed in a gallery of the Janina mine tragic explosion of methane and coal dust at the Halemba mine. Awareness of such dangers causes discomfort to miners and puts pressure on mine administrators to work to prevent such events.

Here there is a large role to be played by scientific research. The long history of mining efforts has produced extensive documentation of events, especially useful for studying the ventilation process in the context of the hazards encountered in mines.

Foreseeing accidents

Over the past decade, the Polish mining industry has seen the introduction of modern equipment for improving miner safety - most notably atmosphere monitoring systems and the VentGraph software package developed by the PAN Strata Mechanics Research Institute, for use by mine dispatchers and ventilation engineers. Monitoring systems supply dispatchers with extensive measurement data from sensors situated at crucial locations throughout the mine, which provide real-time information about concentrations of methane and carbon dioxide, temperature, and airflow speed. The VentGraph software is used to digitally visualize all the mine excavation areas, producing a virtual model of the mine. This model can be used to simulate ventilation processes under both normal conditions and during a state of emergency.

Though VentGraph employs great computational power, its development has prioritized ease of use and easy interpretation of its output. The software builds a vast base of data about the mine under analysis, including information about the spatial layout of the mine's ventilation network and the parameters characterizing the flow of gas mixtures. Such data serves as the basis for calculating air and gas flows under both normal and emergency conditions. VentGraph's "virtual mine" is therefore ready to react to any and all situations. The VentGraph system has already been implemented at most Polish mines and at many foreign ones, including in Australia, the UK, the Czech Republic, and the US.

Numerical simulation of such dangerous phenomena as subterranean fires, or the influx of thousands of cubic meters of methane and its subsequent migration along the mine's ventilation routes, can aid air quality control and - more importantly - ensure that measures are taken to minimize the danger before any accident occurs. The task of predicting changes in gas concentrations under emergency or catastrophic situations is difficult, due to the highly dynamic phenomena involved. However, it can be resolved through numerical simulation, describing the functioning of the entire mine ventilation system, consisting of the excavation areas, hubs, and ventilation devices. Such a simulation requires a mathematical model to be created, taking account of the physical phenomena influencing airflows in a real mine. The initial conditions describe the state of ventilation network flows just before an event occurs, while the limit conditions specify how the ventilation system is impacted by specific factors - a rock shift, outbreak of fire, methane influx, or fire-extinguishing efforts. Numerous cases have shown that the VentGraph software, firmly grounded in research, is an effective tool in fighting the dangers present in coal mines the world over.

Grzegorz Hawałej/FOTORZEPA

A methane explosion at the Halemba mine in Nowa Ruda on 21 November 2006 cost the lives of 23 miners

Marta Błażejowska/AG

Real-life situations

On 22 November 2005, a sudden coal outburst from seam 409/4 took place in transport gallery D-6 of the Zofiówka mine, with an influx of 15,000 m^3 of methane into the excavation. That sudden and unpredicted event brought a dangerous situation - an explosive mixture of air and methane flowing along the ventilation routes. Precise information about such phenomena is crucial for ventilation engineers, especially about the order and timing in which the mine's excavation areas become filled with gas, the methods for degassing them, and the stability of the ventilation system after the outburst.

To envisage how the dangerous situation at the Zofiówka mine would develop, a numerical simulation of the methane outburst's impact on the ventilation system was performed. Such a study was possible because the mine possessed an up-to-date, VentGraph-standard database. The outcome took the form of a map of the mine excavation structure and ventilation routes, showing where the methane was headed, causing a serious threat of explosion. Fortunately, the efficiently functioning monitoring system turned off the power supply, thus minimizing the risk of explosion.

Another incident involved modeling the process of ventilation in the region of the N-303 face in seam 307 of the Bielszowice mine, which had been upset by a rapid methane influx resulting from a strong seismic shock. The risk of an underground shock is always present. The mine's existing monitoring system is good at safeguarding the region of ongoing excavation, yet faced with an emergency situation involving an influx of 253,000 m^3 of methane, as in this case, this system could prove ineffective, especially outside the region of excavation. This was because not all excavations were outfitted with methane sensors. Here the VentGraph system proved useful, owing to its ability to simulate the mine virtually. Such simulation allows the evolution of the methane's spatial distribution after a sudden outflow to be traced, and can check whether the concentration of explosive gas exceeds the safe level.

A gas with a lower density than air, methane flows from the bottom of a face towards the roof. This simulation confirmed that this effect was additionally reinforced by additional air flowing in from the ventilation ducting, which showed a tendency to chiefly ventilate the lower regions of the excavation. The phenomenon was most in-

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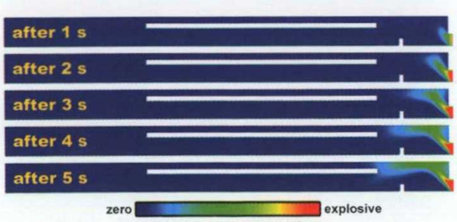

Numerical simulation of the dispersal of methane after its emergence from the gallery lead

Marta Błażejowska/AG

A methane explosion captured on film, at the "Barbara" Experimental Mine in Mikołów

tense during the first five seconds and then a state of relative balance arose, involving a drop in the speed of methane upflow from the bottom of the face.

Subterranean fires

Another example involves the most hazardous situation - analyzing the flows of combustion gasses after the occurrence of an underground fire in an Australian mine, and developing a strategy for employing a gas fire extinguisher to put out such a subterranean fire. This latter device is equipped with a jet engine that produces a large quantity of exhaust gasses (up to 18 m^3/s) containing no more than 2% oxygen - such gasses alter the atmosphere in the fire region and thereby extinguish the flames.

The use of such an extinguisher apparatus strongly disturbs airflows, causing an oxygen shortage that poses a threat to any miners in the mine. That is why it is useful for rescue personnel to be able to simulate the device's operation in a virtual mine, so as to develop strategies of action for many possible scenarios.

Creating a "virtual mine" which faithfully recreates the existing excavations and their airflow parameters requires that a great number of ventilation measurements be taken. The Polish mining industry possesses state-of-the-art measurement devices adapted for working under difficult mine conditions: the μBar pressure gauge (developed in cooperation with the EMAG Center, Katowice), the μAS-4 vane anemometer and the μTh thermohygrometer, developed and produced at the PAN Strata Mechanics Research Institute, Kraków.

Modern measurement and computer techniques plus inventive ideas for how to use them are bringing ever-greater safety to the mining profession, which for many centuries has involved an inherent deadly risk. Yet the mine accidents which do still occur - such as the recent explosion at Halemba, costing the lives of 23 miners - demonstrate how much work remains to be done. Methane outbursts will still occur, especially in coal mines, but simulating such events in a virtual mine can minimize the risk of a dangerous accident affecting real miners. ■

Further reading:

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